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Astrometry and Astromechanics*

By PETER VAN DE KAMP

An attempt is made to present modern astrometric knowledge obtained since Newton's time, as a foundation of the principles of astronomical mechanics. A combination of Kepler's Third Law with these principles leads to Newton's law of gravitation.

It is believed that the presentation is sufficiently novel to justify its inclusion in the current series of astronomical summaries.

1. *Introduction and Summary.*

The historical sequence of discoveries leading to Newton's law of gravitation forms one of the most brilliant and fascinating chapters in the history of astronomy, physics, and mathematics. The first important step was the heliocentric description of planetary orbits, with uniform circular motion, by Copernicus (1543). Later the accurate observations of Tycho Brahe furnished the material from which Kepler derived an accurate space-time description of these orbits, contained in his three laws (the first two were published in 1609, and the third one in 1619):

I. The orbit of each planet is an ellipse with the sun at the focus.

II. The line joining planet and sun sweeps over equal areas in equal intervals of time.

III. The ratio of the cube of the mean distance from the sun to the square of the period is the same for all planets.

On the other hand, the motion of terrestrial bodies had been studied by Galileo, Huygens, and others. The resulting knowledge was summarized by Newton in the three laws of motion:

1. Every body persists in a state of rest or of uniform motion in a straight line unless acted upon by a force.
2. The acceleration is vectorially proportional to the force, and inversely proportional to the mass of the body.
3. To every action there is always an equal and contrary reaction; or, the mutual actions of any two bodies are equal and oppositely directed.

By combining Kepler's laws of planetary motion with these laws of terrestrial motion, Newton derived a single comprehensive statement which was also found to describe the motion of the moon and other planetary satellites, and of falling bodies near the surface of the earth. This law is expressed as follows: Every particle of matter in the universe attracts every other particle with a force that varies directly as the product of their masses, and inversely as the square of the distance. In formula:

$$F = G\,(\mathcal{M}m/r^2), \qquad (1)$$

*The third paper in the series of Astronomical Summaries.

where G is assumed a universal constant, whose value depends on the choice of units. The simple form of Newton's law of attraction has proven an accurate basis for predicting the motions of celestial bodies. The only serious discrepancy, namely the advance of Mercury's perihelion, is fully explained by Einstein's law of inertia. Although the latter is a further improvement, Newton's description is generally adequate in astronomy and we therefore have felt justified in developing the following classical considerations.

We replace the laws of terrestrial motion by *principles of astromechanics* based on the new knowledge of proper motions and orbital motions of stars, obtained since Newton (section 2). First we note the convenience of referring all motions to any group of stars (sections 3, 4, 5). Then the inverse square character of cosmic attraction is noted for the binary stars (including the sun-planet binaries). It is further inferred that the idealized abstractions of elliptic and linear inertial orbits represent particular cases of the inverse square law of cosmic attraction or inertia (section 6). The results obtained are stated in the form of principles of astromechanics; the notion of *mass-ratio* is derived from the space-time behaviour of double star components (section 7). Finally these principles are synthesized with the aid of *Kepler's third law* into the comprehensive law of cosmical inertia, or gravitation (sections 8, 9), which now contains the masses of the pair of accelerated objects. A brief mention is made of "falling bodies" (section 10), and of the related problems of stellar multiplicity and stellar masses (section 11).

The notions of space, time, and mass and their respective additive properties are thus inferred from the observed motions of stars; conversely, these motions are considered *inertial* in character, *i.e.,* described in terms of the three components: *space, time,* and *mass,* through the comprehensive *law of cosmical inertia.* No new results are obtained but this alternate, classical presentation has a systematic character corresponding to our present observational knowledge. Acceleration and mass are emphasized, while the notion of force is omitted. Apart from this the present outline stands only humbly in the protective shadow of the gigantic historical structure that has preceded.

2. *The New Data on Cosmical Motions and Parallaxes.*

In Newton's time knowledge of astronomical mechanics was limited to bodies in the solar system. It was not until 1718 (nine years before Newton's death) that the first stellar motions were discovered. At that time Halley showed that Sirius, Betelgeuse, Aldebaran, and Arcturus had moved appreciably from the positions observed by Ptolemy (these proper motions are to be distinguished from precession, a general rotational motion of the celestial sphere around the poles of the ecliptic, ascribed to the spinning top motion of the Earth's axis of rotation). It was not until 1803 that Herschel announced the discovery of relative

orbital motion in double stars, and not until 1838 that the first successful determination of a stellar distance was made by Bessel. At present thousands of stellar distances have been measured, proper motions have been derived for some hundred thousand stars, and relative orbital motions have been studied in hundreds of double stars. The modern accurate parallax determinations are all made by photography with long-focus refractors[1]; our present knowledge of orbital motions and proper motions depends to a great extent on photographic methods also.

Each annual parallactic orbit, whose size depends on the distance, is simply another of Ptolemy's epicycles. While for the planets these annual reflex motions lead to not too simple resultant motions especially for the inner planets, they are usually well separated from the star's own motion, which generally (see section 4) appears unaccelerated during the interval of a few years over which conventional parallax determinations extend. These annual parallactic orbits, observed for thousands of stars, not only confirm the Copernican viewpoint, but they would have pointed to it if the sun and other planets had been of too feeble luminosity to be observed.

In addition to this vast expansion of astrometric knowledge, the third spatial component—the line of sight—entered into the realm of observations at the end of the nineteenth century. These radial data depend on the interpretation of shifts of spectral lines as Doppler-shifts. In principle the results thus obtained are in full agreement with those of astrometric origin. In the present paper, however, we shall limit ourselves to astrometric data and introduce the spectroscopic data only occasionally.

3. *Reference Frames. Heliocentric Positions.*

The astrometric observer is concerned with the relation of points in space and time; coordinate systems enter only as intermediate useful accessories. In our classical, *i.e.*, pre-relativity presentation they are assumed to be extended Euclidean abstractions of the limited spatial relations revealed to us by matter. It should be noted that we observe the stars as points, since the observations that we are concerned with cannot establish any apparent disks.*

The space-time behaviour of the star-points is studied with the meridian circle, the visual refractor (micrometer, heliometer), or by photography.[2] In the last case, which is important because of its high accuracy, the positions are measured usually in a rectangular coordinate system, the conventional one being closely oriented to the equatorial system. The results thus obtained are directly comparable with positions measured with the meridian circle. The ideal classical reference system, namely a number of extra-galactic objects, has not yet reached the stage of practical application and we therefore use an

*There remains to be studied the problem of spurious disks inherent in our technique (diffraction disks, size of photographic image).

intragalactic reference system based on stars. Three or four faint reference stars usually form an adequate "background" frame for a photographic study of an individual star. A more comprehensive reference frame is ordinarily used in meridian circle observations, which are measured in the equatorial coordinate system and referred to the sun. The photographic astronomer allows for the earth's rotation (and precession) directly through the medium of an equatorial mounting and driving mechanism; the meridian circle astronomer does it indirectly through a sidereal clock.

The observational astronomer has always been explicitly aware of the usefulness of the "fixed" stars as an ideal frame of reference for studying the motions of celestial bodies. Kepler's laws refer to this reference system, and the motions of both single and double stars take on an extremely simple form when refered to a group of "fixed" stars. In classical language, any group of stars forms an ideal approximation to a Galilean or "inertial" system, thus implying that the rotational and precessional motions of the earth are considered "real." The usefulness of such reference systems lies in the fact that most of our astronomical problems have covered a brief interval of a few centuries at most, during which the relative proper motions of the stars have remained virtually constant. Individual dynamical accelerations in the galactic gravitational field are not yet observable, although several statistical properties of stellar motions point to a general state of rotation for our galactic system. In comprehensive studies of stellar motions very small galactic rotation effects are sometimes taken into account; these effects do not, however, affect the practical usefulness of the inertial systems in our present study.

We have seen that for both stars and planets the space-time relations are much simplified by placing the origin of description at the sun. Correcting the observed position of a star for the annual parallactic effect, *i.e.*, the displacement due to the annual periodic motion of the earth, the so-called *heliocentric* position is obtained; the name indicates the sun as a reference point, but it is easily seen that the position refers to whatever point in the earth-sun system is free from this annual motion. Since spectroscopic observations of this annual orbit give the same size as direct geometric methods, we conclude that the annual parallactic motion takes place, with a high degree of approximation, around a point close to (the center of) the sun. From the observer's standpoint the expression "heliocentric" is thus justified for all practical purposes.

4. *Proper Motions. Single Stars.*

The point of immediate interest is the dependence of the heliocentric positions on the time. (We shall ignore here the negligible distortion in any "fixed" reference system due to the motions of the reference stars.) The remarkable result is that the overwhelming majority of

stars exhibit a linear relation between apparent position and time, *i.e.*, a *constant proper motion.* The number of objects taking exception to this rule is exceedingly small as demonstrated for example by the new General Catalogue of 33,342 stars, brighter than magnitude 7.5, by Boss and his collaborators.[3] Of these only 25 objects, or less than one-tenth of one per cent fall outside the rule, although for thousands of the stars in the catalogue observations were made every few years over a period well exceeding a century.*

The results of the new General Catalogue are confirmed by photographic measures of these and fainter stars although the number of exceptions is becoming higher with increasing time and accuracy. Here we have another example of the relative ease with which a "universal" law is established, provided the accuracy is of the right order, *i.e.*, adequate but not too high. The validity of this statement is of course well known for the case of the laws of planetary motion. Our present accuracy shows appreciable deviations (perturbations) from Kepler's laws of motion; at first these deviations could not be detected very well. This facilitated the discovery of Newton's Law of Gravitation from which in turn the very deviations were predicted and described.

5. *Variable Proper Motion. Double Stars. Inverse Square Law.*

Now we turn to the exceptional objects, which within the available resolving power form less than one-tenth of one per cent of the new General Catalogue. Aided in a few cases by telescopic knowledge beyond the reach of the meridian circle, it is found that in all cases these objects are *double stars,* or binaries, whose small apparent separation and approximate equality in proper motion strongly suggest an enduring spatial proximity. The abundance of this type of objects is greatly increased through photographic studies,[4] and the hypothesis of spatial proximity has always been confirmed whenever the parallaxes of the two components have been measured. For these objects the *proper motion* of each component is *variable, i.e.*, neither component follows a non-accelerated path, but for each system it is found that the line joining the two stars can *at all times* be divided in a *constant ratio* so that, within the existing accuracy, the point of division has a non-accelerated motion. The value of the ratio appears to vary from one binary to the other; for the high ratios the division point is always closest to the brighter star. It should be remarked that among the stars of the new General Catalogue there are hundreds more binaries which appear as "pseudo-single" stars, either because any possible variable proper motion is hidden within the errors of observation or because the observed blended image of both components corresponds closely to the non-accelerated division point just mentioned.

*The accuracy of the meridian circle observations, on which the catalogue is based, is such that the angular displacement for these stars is at present not sensibly affected by any acceleration effects of perspective origin.

A study of proper motions therefore reveals that single stars follow a non-accelerated path; for double stars in close spatial proximity there is a uniquely defined point between the two stars which follows a non-accelerated path. The constant ratio involves similar orbits of the two components with respect to the division point; the orbits differ in size, and 180° in angular phase. Although potentially these separate "absolute" orbits can be studied, a large amount of accurate observational material has been obtained in addition, through a study of the relative orbit of the two components in which one of the stars is considered at the origin. (In considering the motion of each star with respect to the division point, the latter is at the origin. The relative and absolute orbits are, of course, similar.) Historically, double star astronomy has developed that way and for wider pairs has reached a particularly high accuracy, during the last twenty-five years, through the photographic observations initiated by Hertzsprung[5] and later continued by Strand.[6,7] Provided the accuracy is adequate, *i.e.*, neither too low nor too high, it is found that the relative motion of the two stars takes place in an ellipse and that the line joining the two stars sweeps over *equal areas* in *equal times*. Since the observed elliptic motion is a projection, the relative motion in space must be elliptic also, and it is found (as of course strongly suggested by the historically earlier discoveries by Kepler for planetary orbits) that an elliptic motion in space subject to the law of areas relative to the focus ("Kepler motion") satisfies the observations.

Now, a relative motion of two points, subject to the "law of areas," implies at all times a relative acceleration, in the attractive sense, along the line joining the two points. If, moreover, the relative orbit is an ellipse with the origin at the focus, simple kinematical considerations show that the relative acceleration, q, is inversely proportional to the square of the distance r. For, using the natural polar coordinate system, the equation of the conic section is

$$r = p/(1 + e\cos v), \tag{2}$$

where r is the radius vector, v the true anomaly, and p the parameter which for the case of the ellipse is related to the semi-axis major a and the eccentricity e by the formula:

$$p = a\,(1 - e^2). \tag{3}$$

Now Kepler motion is described by equation (2) in conjunction with the law of areas: $r^2\ (dv/dt) = \text{constant}$. The general expression for acceleration along the radius vector,

$$q = d^2r/dt^2 - (dr/dt)^2, \tag{4}$$

for the case of Kepler Motion becomes

$$q = \mu/r^2, \tag{5}$$

where

$$\mu = 4A^2/p, \tag{6}$$

A being the constant areal velocity $r^2/2(dr/dt)$.

For the present study we are not concerned with parabolic and hyperbolic orbits, since they would trespass on the "reasonably long temporal conditions" of our observations. The restriction to "closed," *i.e.*, elliptic, orbits suggests the introduction of their space-time dimensions: the semi-axis major a and the period of revolution P, which are related to the areal velocity as follows:

$$A^2/p = \pi^2 \times a^3/P^2, \tag{7}$$

so that the following kinematical expression for μ is derived:

$$\mu = 4\pi^2 \times a^3/P^2. \tag{8}$$

When the absolute orbit of each component with respect to the division point is considered, q and a represent the corresponding acceleration and semi-axis major. For the relative orbit of the two components, q and a represent the relative acceleration (*i.e.*, vectorial difference) and semi-axis major.

A Correction

Following is an important correction to be made on page 58 of the preceding issue (February, 1944).

Formula (4) should read $q = d^2r/dt^2 - r\,(dv/dt)^2$,

and the last line on the page should be

A being the constant areal velocity $r^2/2\,(dv/dt)$.

suffer no acceleration, this is the counterpart of the classical law of *inertia*. Furthermore, observations show that as soon as an acceleration exists, a point obeying the law of inertia can be assigned close to the star; this point we shall call *inertial point;* in most cases it has turned out to be a point at the "characteristic" location between the star and a companion star. But even when this companion star is not found, the primary star is always found to describe a Kepler motion around the inertial point, thus suggesting the inevitable, though possibly not yet seen, companion object. The classical examples are the discoveries by Bessel of the variable proper motion of Sirius and Procyon; the unseen companions were discovered later, thus establishing these two objects as visual binaries. In several cases the inertial point has turned out to give only temporary satisfaction as a "linear" inertial point; its motion has proven to be elliptic, thus indicating a further stage of multiplicity.

The introduction of the inertial point has the advantage that it enables us to maintain the *classical* or *"linear" law of inertia,* which can now be said to hold for either single stars or properly defined inertial points in double stars. There can be further unity in statement. While for the

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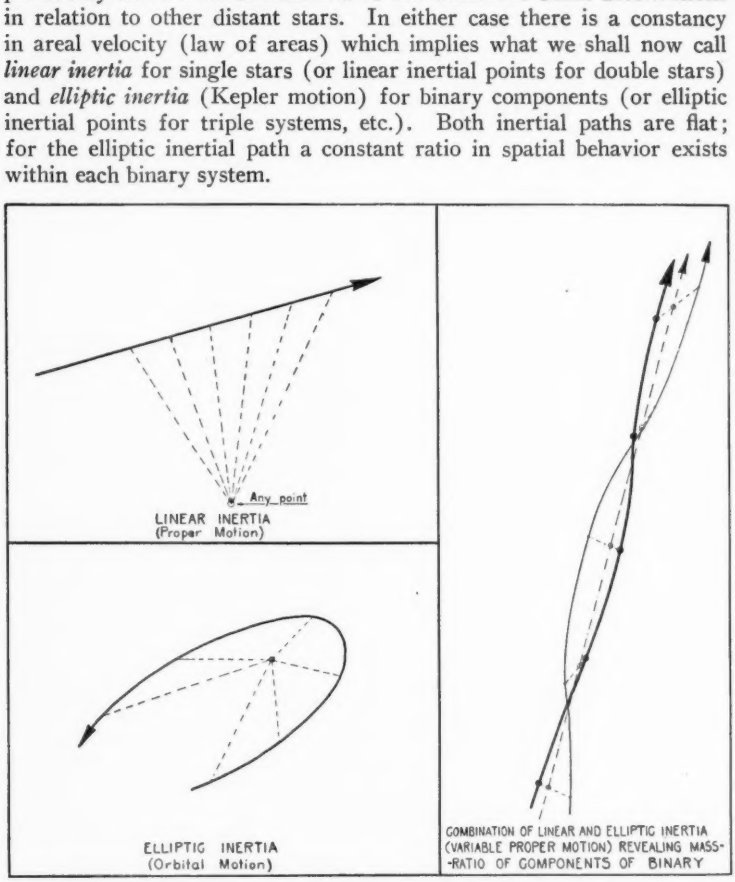
Thus the simple important result is found that the relative acceleration of Kepler motion in a binary is inversely proportional to the square of the distance of the components. Observations of different binaries have revealed that the period of orbital motion shows an increase with the separation of the components in such a way that there appears to be a rather limited range in the factor of proportionality μ. Thus proximity appears to play the predominant rôle in causing observable accelerations.

6. *Inertial Point. Linear and Elliptic Inertia. Inertial Constant.*

Reviewing the results on proper motions (section 4) and variable proper motion (section 5), we see that in the conventional astronomical reference frames "single" stars, sufficiently far away from other stars suffer no acceleration; this is the counterpart of the classical law of *inertia.* Furthermore, observations show that as soon as an acceleration exists, a point obeying the law of inertia can be assigned close to the star; this point we shall call *inertial point;* in most cases it has turned out to be a point at the "characteristic" location between the star and a companion star. But even when this companion star is not found, the primary star is always found to describe a Kepler motion around the inertial point, thus suggesting the inevitable, though possibly not yet seen, companion object. The classical examples are the discoveries by Bessel of the variable proper motion of Sirius and Procyon; the unseen companions were discovered later, thus establishing these two objects as visual binaries. In several cases the inertial point has turned out to give only temporary satisfaction as a "linear" inertial point; its motion has proven to be elliptic, thus indicating a further stage of multiplicity.

The introduction of the inertial point has the advantage that it enables us to maintain the *classical* or *"linear" law of inertia,* which can now be said to hold for either single stars or properly defined inertial points in double stars. There can be further unity in statement. While for the

components of a double star the law of areas holds when referred to the inertial point, this law obviously also holds for this inertial point, and for single stars, when referred to any reference point; this is explained by the virtual cancellation of the numerous small accelerations in relation to other distant stars. In either case there is a constancy in areal velocity (law of areas) which implies what we shall now call ***linear inertia*** for single stars (or linear inertial points for double stars) and ***elliptic inertia*** (Kepler motion) for binary components (or elliptic inertial points for triple systems, etc.). Both inertial paths are flat; for the elliptic inertial path a constant ratio in spatial behavior exists within each binary system.



THE OBSERVATIONALLY SELECTED FORMS OF INERTIAL PATHS IN ASTROMETRY.
(The dashed lines refer to equal time intervals.)

We thus notice the emergence of two kinds of Euclidean paths in classical astromechanics, related to each other through the law of areas. Apparently both elliptic and linear inertial motions are idealized selective abstractions which within the available space-time range are abundant; the elliptic inertial motion because of an obvious cosmic tendency for close proximity of stars in double and multiple systems, the

linear inertial motion because of the relatively large ratio between the spacing of single systems and the short time interval entering into most of our studies. In either case the inertial paths in our present astrometric studies are thus selected by observational limitations in space, time, and accuracy. For example, with sufficient resolving power applied to the proximate components of star-star, sun-planet, and planet-satellite binaries the corresponding "linear" inertial time interval is much reduced and the law of linear inertia turns out to be a differential portion of the "elliptic" inertial path. For a specific object the motion can often be described as a resultant of linear and elliptic inertial components, the accuracy of the description being dependent on the extent of the space-time survey and the observational accuracy.

The inverse square law

$$q = \mu/r^2 \tag{5}$$

can thus be considered a general law of cosmical inertia, which through observational selection is conspicuously revealed in the two abundant component forms of linear and elliptic inertia. The characteristic factor μ will be called the *inertial* constant of the binary.

7. *The Principles of Astromechanics. Mass-Ratio and Mass.*

The foregoing considerations are now presented in the form of principles of astromechanics, which thus are abstractions within the limits of the observational resolving power.

I. Any two stars are subject to a mutual acceleration in the attractive sense and localized along the line joining the two stars; this acceleration is at all times inversely proportional to the square of the distance between the stars.

II. A single star, sufficiently far away from other stars has a non-accelerated motion for a reasonably long time. This is expressed by saying that a single star has the property of (linear) inertia.

III. For any two sufficiently proximate stars a characteristic ratio exists, determining at any time a division point on the line joining the two stars; this "inertial point" obeys postulate II.

The stars are referred to a more or less comprehensive system of other stars; in the language of terrestrial mechanics either frame or one with a relative non-accelerated motion is a satisfactory inertial or Galilean reference system. We note that "sufficiently far away" and "reasonably long time" are not specified any further. These classical principles are thus more or less valid depending on the observational limitations in space, time, and accuracy. Thus principle II is also found to hold for any binary star which falls sufficiently below the observational resolving power; such pseudo-single objects behave like single stars or linear inertial points.

Obviously the characteristic ratio in postulate III is of significance

because of its *constancy* in space and time and it therefore should be studied further. The law of (linear) inertia holds for the division point, which thus represents a "singleness" or inertia of character analogous to that of a single star. For a binary star this inertial property is revealed in a "split" fashion in the sense that it is deviated from by both components but it is approached most closely by the spatially nearer one. On this basis we choose to consider the inertial point as a weighted (in the sense of relative values) mean representation of scalar properties assigned to each component. The property thus defined will be called *mass,* and like the characteristic ratio it is assumed to be constant over a reasonably long interval. The observed characteristic ratio is thus a measure of the (inverse) *ratio of the masses* of the binary components. The component points maintain elliptic inertia with respect to the common inertial point; for "short" time intervals linear inertia is maintained within the limitations of the observational resolving power showing the difference in mechanical behavior between binary components and "single" stars to be of degree and not of kind.

Observations have revealed that the mass-ratio shows a strong correlation with the luminosity ratio, in the sense that the brighter star is always nearest the division point. We therefore cease to consider the stars as mathematical points only, but become aware of them as physical points, possessing varying degrees of brightness. From spectroscopic observations we know the stars to be radiating bodies, whose different luminosities can thus be attributed to differences in size and surface temperature. The mass-ratio of the stars thus enters as a ratio of properties involving the physical structure of the, still, point-like components. A useful *definition* of mass-ratio is reached by realizing that the constancy of the characteristic ratio involves the spatial elements and their temporal derivatives. Apart from "initial" conditions of relative location and velocity (linear inertia) the (past and future) course of the binary components is completely described through the relative attractive acceleration and the mass-ratio. Since the latter implies a constant ratio of the accelerations of the two components with respect to the inertial point we introduce the following definition:

A. The inverse of the opposite accelerations of the components of a double star is called the mass-ratio of the two stars.

The inertial point will now be called the *center of mass* and, through the use of definition A, principle III can be revised to read:

III. For any two sufficiently close stars, a certain mass-ratio exists, so that the center of mass has the property of (linear) inertia.

Because of the dependence on resolving power the distinction between single and double (and multiple) stars is strongly influenced by the observational accuracy and the difference in observational revelations is thus more or less artificial. With relatively low resolving power

the notion of mass-ratio dissolves and ceases to exist fom the observational standpoint, but the property of (linear) inertia remains. We now postulate that in such a case the mass of the "pseudo-single" star is the sum of the corresponding properties of the components. Thus we have the final principle:

IV. The mass of the total of several points equals the sum of the masses of the individual points.

8. *Kepler's Laws of Planetary Motion.*

To recapitulate: we have seen how observations of double stars have revealed the presence of a continued state of inertial motion in the universe, described by the law of attraction between the components,

$$q = \mu/r^2, \tag{5}$$

where for the case of elliptic inertia or Kepler motion

$$\mu = 4\pi^2 \times a^3/P^2. \tag{8}$$

Here q is the relative acceleration, r the distance between the components, while μ, the inertial constant of the binary, can be expressed in term of the orbital dimensions a and P.

Now the notion of mass has been revealed through the behavior of binary components and the question arises whether and how mass enters in the law of attraction through the inertial constant μ. Another question is this: Each binary system gives us a value for its mass-ratio, *i.e.*, the relative value of the quantity defined as a mass. Can this notion of mass be put on a more comprehensive basis so that the masses of components in different binary systems can be compared? We think immediately of the triple, quadruple star systems, which occur frequently. Observations of multiple stars have shown that in all cases the space-time dimensions are of different order within any one system, so that as a first approximation the resulting binary motion may be dissected in two or more separate motions (*cf.* Sun-Earth-Moon system). The present observational data however are hardly adequate yet for any serious progress along these lines.

The ideal complimentary data for the answer to both questions are provided by the multiple system of the sun and its planets, which can be considered a series of binary systems formed, in a certain sense, by each planet and the sun. Now for the first time, because of very high observational resolving power, we come in contact with bodies which are not points any more (although the planets were points to Tycho Brahe and Kepler). This difficulty turns out to be happily solved (section 9) because the distances involved are so large that as a first approximation sun and planets may be considered as points. We shall thus represent the sun, as Kepler did in his laws, by a point at the center of the sun.

That the planetary system can be so obviously dissected into a series of "binaries" means that as a first approximation the relative accelera-

tions of the planets to each other are negligible and that only their relative motions to the sun need be considered. It is further important to remember that any observed stellar motion contains a secular parallactic component which is the reflex of the motion of the center of mass of the sun and earth with respect to the group of stars including the star under consideration. We have already seen (section 3) that for the Sun-Earth system the sun represents the state of "singleness" or linear inertia with a high degree of approximation. This must also be true for the other sun-planet binaries; an appreciable deviation from singleness for the sun, caused by Jupiter, for example, would be revealed as a twelve-year period in the observed stellar positions, which never has been found. The state of motion in the planetary system being expressed with a high degree of approximation by Kepler's laws, we understand now that these laws imply a high relative mass for the sun.

The first two laws of Kepler give results consistent with those derived from the observed orbital motion of stellar binaries, *i.e.,* they are simply another revelation of the first principle of astromechanics. They lead to a relative acceleration in the attractive sense, localized along the line joining planet and sun; this acceleration is at all times inversely proportional to the square of the distance between planet and sun.

The new and crucial information with regard to the inertial constant μ is now obtained through Kepler's third law, which is a peculiar property of the solar system:

$$a^3/P^2 = C_p. \tag{9}$$

Here C_p is almost constant, varying but slightly (below one per cent) from planet to planet.

For each planet the relation (8) holds; for all planets the relation (9). Substitution of (8) in (9) leads to the following relation, valid for each sun-planet binary:

$$\mu = 4\pi^2 \times C_p. \tag{10}$$

Thus the inertial constant is found to vary but very slightly from one sun-planet binary to the other.

9. *The Law of Cosmical Inertia.*

We have seen how the existence of Kepler's laws as accurate though approximate descriptions of the planetary courses has been attributed to the dominant mass of the sun. We therefore seek to correlate the minute values of the relative mass $m/\mathcal{M}$ of the planets with the minute range in the inertial constant μ for each sun-planet binary. This is accomplished by putting descriptive emphasis on the inertial point, *i.e.,* center of mass of planet and sun; the acceleration q_p of the planet to the inertial point is related to the relative acceleration q of the planet and sun as follows:

$$q = q_p\,(1 + m/\mathcal{M}). \tag{11}$$

The inverse square law (5) now takes the form

$$q_p\,(1 + m/\mathcal{M}) = \mu/r^2. \tag{12}$$

The quantities $1 + m/\mathcal{M}$ and μ are constant for each (sun-planet) binary. Separating the constant from the variable parts, we have

$$\mu = \gamma_p (1 + m/\mathcal{M}), \tag{13}$$

and

$$q_p = \gamma_p (1/r^2), \tag{14}$$

where γ_p is constant for each orbit.

The minute range in μ, and in $1 + m/\mathcal{M}$, leads us now to the hypothesis that the factor of proportionality γ_p is the same for all sun-planet binaries, so that we shall drop its subscript *p:*

$$\mu = \gamma (1 + m/\mathcal{M}), \tag{15}$$

and

$$q_p = \gamma (1/r^2). \tag{16}$$

The asymmetrical relation (15) for μ is obviously due to the asymmetrical mass-relation in the sun-planet binaries; stellar binaries have not been found to exhibit such strong structural asymmetry. Assuming the same mechanical law to be valid for star-star and sun-planet binaries, the next step is to make the expression (15) symmetric with respect to the two bodies by writing

$$\mu = (\mathcal{M} + m)\, \gamma/\mathcal{M}, \tag{17}$$

or, replacing $\gamma/\mathcal{M}$ by G,

$$\mu = G (\mathcal{M} + m), \tag{18}$$

where G thus is a *constant* for all *sun-planet* binaries. The inertial constant μ is thus found to represent the sum of the masses of planet and sun; the law of attraction (5) for the sun-planet binaries therefore takes the form

$$q = G (\mathcal{M} + m)/r^2. \tag{19}$$

Thus the *relative acceleration* is found to be *inversely proportional* to the *square of the distance* and *proportional* to the *sum of the masses;* for either component the acceleration relative to the inertial point (center of mass) is proportional to the mass of the other component. The equivalence of Newton's law (1) with (19) follows from the definition of force contained in his laws of motion. Newton has already shown that the expression holds equally well for point masses as for bodies having spherical symmetry in the distribution of their constituent masses, provided we assign to mass the additive property. This justifies our representing the sun by its center.

The expression (19) states Newton's law of attraction, which has thus been derived from a study of *astronomical mechanics* only. Although the inverse square character of the law of cosmical inertia (5) was already revealed by binary stars, the third law of Kepler was needed to give the proper significance to the inertial constant μ. The notion of *mass-ratio* as revealed by binary stars was then assumed to be valid in the solar system and μ found to be proportional to the sum of the masses of the two component bodies of the binary pair. As a matter of convenience and faith we assume G to be the same for all stellar binaries and for the assembly of sun-planet binaries; this leads, strikingly, to a

small dispersion in their inertial constants, *i.e.*, total mass (see section 11). Any interaction between the solar system and stellar systems is beyond the present realm of direct observation.

Newton's law is thus postulated as a universal law of cosmical inertia, describing motion in terms of the fundamental revelations—space, time, and mass. The cosmical concentration of stars in small space-time binary units of comparable mass and the limits of our space-time survey and resolving power give a selective observational abundance of both elliptic and linear inertial paths.

10. *Falling Bodies. Equivalence of the Law of Cosmical Inertia and of Terrestrial Gravitation.*

Newton's faith in the universality of the law was further strengthened by the motion of the moon and of falling objects. From the cosmical viewpoint a "falling" object is an object released in space-time. Apart from any initial velocity deliberately imparted by the terrestrial release agency, the falling object always starts with the motion due to the rotation of the earth, just like an object "at rest" in or near the earth's surface partakes rigorously in this rotation. (Whatever the cause of this rotation is, it admits of a simple description in any reference system as formed by a group of stars.) From the moment that the object severs any physical connection with the terrestrial release agency, it becomes a "free" body which, apart from hindrance by atmospheric resistance, appears to obey the universal law of attraction; it may be considered the second component of a binary of which the earth is the principal component. From an external cosmical viewpoint the falling body would follow an elliptic inertial path, relative to the center of the earth, except at the poles where the path degenerates to a straight line; in any case the motion is soon interrupted because of the distended physical shape of the earth.

We are now particularly interested in the shortlived part of this elliptic course as referred to a plane tangent to a point on the rotating earth ("horizontal" plane); this is conventionally referred to as "falling" motion. Experiments have shown that in any particular locality at the earth's surface the acceleration of this falling motion is the same for different bodies. We shall now show that this result is in accordance with the law of cosmical inertia. According to the latter a central acceleration exists between the object and the *center of the earth*. Assuming for the present argument spherical symmetry in the earth's mass structure, this acceleration is given by

$$q = G\,(\mathcal{M} + m)/r^2. \tag{19}$$

Here $\mathcal{M}$ is now the earth's mass, m that of the "falling" object, and r the radius of the earth.

Let us first consider a falling motion without any initial velocity except the inherent local velocity of the earth's rotation imparted by the terrestrial release agency. The kinematical description of this circular

motion requires a central acceleration

$$V^2 \cos \phi / r \qquad (20)$$

perpendicular to the axis of rotation. Here V is the equatorial velocity of rotation; ϕ the latitude of the place of observation.

The acceleration (20) has a local vertical component amounting to

$$V^2 \cos^2 \phi / r \qquad (21)$$

directed to the earth's center, and a local horizontal component of

$$V^2 \sin 2\phi / 2r \qquad (22)$$

directed away from the earth's equator. The acceleration (20) or its components (21) and (22) are, for the physical surface of the earth, provided by the latter's cohesive structure.

We are particularly concerned with the vertical component (21) required to maintain a body in the diurnal circular orbit, which represents the "non-falling" or "weightless" state. This vertical acceleration of the Earth's surface must be subtracted from the inertial acceleration (19) in order to obtain the vertical "falling" acceleration, which thus amounts to

$$q' = G(\mathcal{M} + m)/r^2 - V^2 \cos^2 \phi / r. \qquad (23)$$

An initial velocity imparted deliberately by the terrestrial release agency does not affect the vertical falling motion or the property of elliptic inertia. But it would introduce, relative to the rotating axis, a "horizontal" (Coriolis) acceleration of the nature of (22). An additional horizontal (Coriolis) acceleration at right angles to (22) is in any case introduced, except at the poles, because of the slight excess of initial rotational velocity over that of the earth's surface "below." The acceleration (23) does need adjustment for the oblateness of the earth. We shall not study all these effects in detail but simply note that they are dependent on space and time only and independent of the (mass of the) objects studied. Only the law of cosmical inertia, as appearing in the expression (23), is dependent on the mass of the "falling" body.

So far as the dependence on latitude is concerned, formula (23) gives a good description of the observed falling acceleration, which, expressed in cm/sec^2, is

$$g = 983.2 - 5.2 \cos^2 \phi. \qquad \text{(Helmert, 1896)}$$

The earth's rotation thus influences by less than one per cent the overwhelming effect of the inertial, falling acceleration with respect to the earth's center. The excess of the observed coefficient of $\cos^2 \phi$ over the predicted one (3.37 cm/sec^2) can be attributed to the oblate shape of the earth.

It is now most significant that for any particular locality (constant ϕ) the resultant acceleration is independent of the choice and nature of the falling body, as shown by the beautiful experiments of Eötvös[8] with an accuracy of one part in 20,000,000. This is exactly what one would expect from the law of cosmical inertia if one simply assumes the mass of the earth to be vastly exceeding that of the falling body, so that for

all practical purposes, the first term (19), of (23) may be written as

$$q = G\,\mathcal{M}/r^2. \tag{24}$$

There is then nothing surprising about the virtual equality of acceleration (23), for all falling bodies in any particular locality. It follows accurately from the law of cosmical inertia, adjusted for the earth's rotation and simply implies negligible masses for the falling bodies, as compared with the earth's mass. Thus Newton's law of cosmical inertia, as derived from the astromechanical principles and Kepler's third law, describes the phenomena of terrestrial gravitation completely, and any differentiation between attraction, gravitation, and inertia is unnecessary. The relative acceleration of the moon and the center of the earth is also closely expressed by (24) which not only demonstrates again the validity of the law of cosmical inertia, but also indicates the relative smallness of the mass of the moon.

The tiny gravitational accelerations of the masses of terrestrial objects on each other have been studied through artificial binaries, two spheres of various materials placed at close horizontal range so as to equalize the vertical gravitation of the third body, namely the earth. A relative attractive acceleration is observed and when expressed by the cosmical law $q = G\,(\mathcal{M} + m)/r^2$, it is found that the inertial constant, $G\,(\mathcal{M} + m)$, is proportional to the combined *terrestrial inertia,* or *mass,* of the two bodies as measured by terrestrial *forces* like supporting or weighing, which interfere with the free motion as embodied in the law of cosmical inertia. By definition a terrestrial "force" is proportional to both mass and acceleration and we are thus assisted in "visualizing" the postulated additive properties of mass by their terrestrial revelation of the falling "force," *weight.*

Terrestrial experiments have given a value of $G = 6.66 \times 10^{-8}$ expressed in c.g.s. units. From the observed value of G, and of the earth's radius, a mass of 5.98×10^{27} grams and a mean density of 5.53 for the earth are found. Thus it is explained that even with his wonderful accuracy Eötvös could not detect any differences in falling acceleration.

11. *Determination of Astronomical Masses. Kepler's Third Law. Multiplicity of Stars.*

The total masses of binary systems are conveniently compared through their inertial constants, when these can be computed from the observed space-time dimensions a and P. For a combination of the inertial expression

$$\mu = G\,(\mathcal{M} + m) \tag{18}$$

with the kinematical expression

$$\mu = 4\pi^2 \times a^3/P^2 \tag{8}$$

gives

$$\mathcal{M} + m = 4\pi^2/G \times a^3/P^2. \tag{22}$$

If desired to express the total mass in grams, formula (22) is used, the value G having been obtained from terrestrial experiments (section

10). It is often preferrred to restrict the computations to a comparison with the sun-earth binary. By neglecting the earth's mass and choosing as conventional astronomical units the mean distance from the earth to the sun, the sidereal year, and the sun's mass, we then obtain

$$\mathcal{M} + m = a^3/P^2. \qquad (23)$$

For the solar system in which each planet forms a binary with the sun as the principal component, formula (23) represents the more nearly accurate statement of Kepler's third law.

The sum of the masses in a binary system is thus easily evaluated if adequate knowledge of the apparent orbit and our distance from the object are available. The distribution of the total mass over the two components is further obtained by localizing the center of mass through its inertial path, which may ordinarily be considered linear, but which is elliptical in case of a third component. The practical details for the method of stellar binaries are described in another article by this author.[9] An interesting result is the limited range in stellar masses. The smallest stellar mass accurately known is that of Krüger 60*B* (0.14 times the sun's mass). The largest planetary mass known, is that of Jupiter (0.001 ⊙). Recently Strand has found a third component in the well-known binary 61 Cygni, which seems to have an intermediate mass of 0.016 ⊙. Of further interest is the general increase in mass with luminosity.

We shall finally mention the problem of stellar multiplicity. The spectroscopic method has been especially successful in the discovery of spectroscopic binaries among the brighter stars. The astrometric method is of particular value for nearby objects when applied photographically by long focus refractors. In section 5 it was already implied that with a coarser accuracy the new General Catalogue would not have recognized any binaries; observational selection, dependent on resolving power, plays a vital rôle in the differentiation between single and binary stars. While at greater distances double and multiple objects usually appear as single stars, the discovery of their detailed structure at closer range, particularly the solar system's, has led to the immense structure of Newton's law of cosmical inertia. This very law assists us now in our present studies of stellar multiplicity of star points, whose possible duplicity is below the visual resolving power, but for which the discovery of deviations from linear,—or from elliptic inertia, indicates unseen components. Thus the "inertial resolving power" aids us by increasing our knowledge about the clustering of stars, and possibly planets, into compact cosmical units.[10]

We conclude with a brief report on the present knowledge of multiplicity of stars as observed in our immediate neigborhood where the astrometric resolving power is highest. Of the 38 known stellar systems nearer than 5 parsecs (16.3 light years), the sun is a multiple binary

system in the sense that it is the principal component in a large number of binaries of which planets, comets, etc., are the second components. There are three triple systems; in one of these (61 Cygni) the third component may be planet-like. Of the others, six are double, and several are suspected of duplicity because of their inertial behavior. Clearly then, the picture created in the image of our current space-time survey and observational resolving power points to abundant clustering into binary and multiple systems in our neighborhood; this is possibly also a property of more distant regions.

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SPROUL OBSERVATORY, SWARTHMORE COLLEGE, SWARTHMORE, PENNSYLVANIA, 1943 DECEMBER 30.

The Cincinnati Telescope*

By ROBERT L. BLACK

I

John Quincy Adams had been up since four o'clock on that chilly morning of November 9, 1843, in his room at the Henrie House on Third Street polishing his address to be given at the laying of the cornerstone of the Observatory. Someone from across the street saw him there working in the dim candlelight.

He had been caught unprepared at Lebanon on the way to Cincinnati by the splendid eloquence of Thomas Corwin, called "the wagoner boy" by the voters, ex-Governor of Ohio, later to be United States Senator and Secretary of the Treasury. The Mayor of Cincinnati, Henry E. Spencer, welcoming him the afternoon before from the balcony of the hotel, had, so the papers said, eclipsed all his Honor's previous attempts.

"These premeditated addresses by men of the most consummate

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ability," he had written in his diary, "and which I am required to answer off-hand, without an instant for reflection, are distressing beyond measure and humiliating to agony. . . My answer was flat, stale, and unprofitable without a spark of eloquence or a flash of oratory."

He was a tired old man, worn thin with sixty-two years of constant service to the American people. His daughters had warned him that he was too feeble at seventy-six to undertake a journey of over a thousand miles at an inclement season of the year. But the young professor, Ormsby MacKnight Mitchel, who had come with such overwhelming enthusiasm to the Cataract House at Niagara Falls in July, preceding, had prevailed on him to accept the invitation from Judge Jacob Burnet, president of the Cincinnati Astronomical Society.

"This is a rash promise . . .," he wrote, "it is an arduous, hazardous, and expensive undertaking, the successful performance of which is more than problematical, and of the event of which it is impossible for me to foresee anything but disappointment. Yet there is a motive pure and elevated . . . upon which I may without irreverence invoke the blessing of Heaven, as I do, for fortitude, energy, and perseverance to accomplish what I have promised."

He had left Braintree two weeks before, taking the train to Buffalo. The lake-steamer, *General Wayne,* made a stormy passage to Cleveland, "cold," he said, "as Nova Zembla." It snowed during the four-day trip down the Ohio Canal on the packet *Rob Roy.* The stage-ride from Columbus had been like a royal progress with appearances at every village—Jefferson, Springfield, Dayton, Lebanon—all along the road. He had a headache, fever, chills, hoarseness, a sore throat and his *tussis senilis,* as he called it,—his old man's cough—had returned in full force.

As he finished up at day-break, a national salute of twenty-one guns fired from Mount Ida, re-echoing from the low, heavy clouds, roused the fifty thousand or more inhabitants of Cincinnati. Long before ten they were hurrying to join the procession or to line up along its route. Judge Burnet, tall, swarthy, austere, even forbidding, in a ruffled shirt, wearing his hair in a queue though the fashion had long since changed, and Professor Mitchel, a little terrier of a man, sharp-eyed, talkative, full of bounce, came together to the Henrie House to get Mr. Adams. He trotted down to meet them, a small, neat, quiet personage, still apple-cheeked in spite of his years.

The procession was forming on Broadway near by, its head resting at Third Street. First came the military — the Cincinnati Light Dragoons, the Cincinnati Greys, the Washington Cadets, the Jefferson Riflemen, the German Light Infantry, the Kosciuscko Guards, with others; next the seven hundred members of the Astronomical Society escorting Mr. Adams, in an elegant open barouche drawn by four dun horses; then, the Book-binders, the Chamber of Commerce, the Young

Men's Mercantile Library, the Mechanics Institute; finally, an innumerable crowd of miscellaneous citizens. Everybody, little or big, was there.

"Let it not be said," a clerk had written the day before to the Editors of the *Gazette,* "that the merchants of the city are too mercenary, too wedded to dollars and cents, to give one day to those in their employ."

Just as the order to march was given, the heavens opened, filling the streets with water. Judge Burnet and Professor Mitchel sitting in the barouche with Mr. Adams raised the sides over their heads for shelter. The mingled horse and foot, with banners dripping, paraded to the sound of martial music, half-drowned; the carriages splashed; the citizens tramped through the wet, down Broadway, across Front to Main, up the rise to Sixth, thence to the foot of Mount Ida. The long line wound steeply around the hill up the half-mile of slippery clay road to the top. The little circular plain up there looked like a sea of mud.

"I am not a fair-weather bird," quoth Mr. Adams, "to be frightened by a storm."

A small stage for the speakers had been erected at the edge. In front stood those who wore badges at 37½ cents; the military were formed on either side; the many who had paid two bits for tickets filled in behind. Judge Burnet introduced the "old man eloquent" to the auditory of umbrellas. Mr. Adams read his address rapidly; before he was done, the manuscript was so defaced by the rain as to be scarcely legible.

"The scene before your eyes is covered with edifices," he said, "the corner stones of which have been laid with religious rites, or in the ceremonies of solemnity importing that the purposes of their erection were subservient to the wants, comforts, or enjoyments, not of single families, but of successive multitudes of the race of man. In the midst of the delight with which your hearts will expand, at the contemplation of this cheering view, does your love of the arts and sciences of civilization, which are spreading this enchanting scene before you, prompt the inquiry, whether, among these monuments of civilized industry, perseverance, ingenuity, there is one light house of the skies—one tower erected on the bosom of the earth, to enable the keen-eyed observer of the heavenly vault, and the profound calculator of the infinite series, to watch, from night to night, through the circling year, the movements of the starry heavens, and their unnumbered worlds; and report to you, and to all the civilized race of man, the discoveries yet to be revealed to the tireless and penetrating eye of human curiosity? Look around you, fellow-citizens—look from the St. John to the Sabine —look from the Neversink to the mouth of the Columbia, and you will find, not one! not one! . . ."

Thereupon he laid the corner stone, "invoking the blessing of Him in whose presence we all stand, upon the building which is here to rise, and upon all the uses to which it will be devoted, upon the observators

. . . upon the people of the city where it will stand, and the State, to which they belong; and, finally, upon the North American Union, and the whole brotherhood of *Man.*"

That evening, at early candlelight, the ladies of the city gave a Temperance tea party in Shirer's Garden at Third and Vine Streets, which had once been Judge Burnet's mansion house. Thither Mr. Adams was escorted through the thick mist between a double line of torchlights. Following prayers by the Reverend Lyman Beecher and an address by the Hon. Bellamy Storer, the venerable patriot spoke with the simplest directness and earnestness. He praised the sacred cause of temperance calling it "the emanation of a female mind." After this the three thousand people rushed the eleven hundred feet of tables in the pavilion, loaded with cakes and meats, surmounted, to instill the moral lesson, by a bottle of alcohol encircled by a serpent. Alas, two-thirds of those who had paid fifty cents apiece for tickets (proceeds to the cause) got no refreshments; bonnets were smashed, bustles demolished, bones endangered. It was, in the words of the *Gazette,* the most brilliant, muddy, unique, crowded, strange, and exciting affair.

At 11:00 on the tenth, a Friday morning, Wesley Methodist Episcopal Chapel, still standing today on the north side of Fifth Street between Sycamore and Broadway, was packed to its utmost capacity of 3,000 people, a dense, compact crowd, old and young, rich and poor, spilling out into the aisles.

Judge Burnet again introduced Mr. Adams. He presented the sage and patriot in elegant, sonorous words, with a bit of Shakespeare and a tag of latin verse. The chapel was made to ring again with cheers.

The Oration of Mr. Adams fills sixty closely-printed duodecimo pages—a masterly, scholarly, all-embracing history of astronomy. He begins with the first superstitions of primitive man, sweeps upward through the Greek philosophers, through the moderns, Copernicus, Galileo, Tycho Brahe, Kepler, Newton, Herschel, to the first Struve, Imperial Russian astronomer then living. Written in the grand manner, it is tough reading, heavy, long winded, of a dignity unimpeachable —the sort of thing that one must necessarily revere, but without passion.

Mr. Adams gave them nearly two hours of it, about half of the whole,—showing thereby a kindliness rare among orators. They listened to him in breathless silence, interrupted only, so a newspaper said, "by simultaneous yet suppressed rounds of applause." Mr. Adams went so far as to admit to himself that it was received without any symptom of impatience or inattentiveness.

At the end the audience, calling on the everlasting hills to express their thanks, voted by unanimous shout that Mount Ida, the height where he had laid the cornerstone the day before, should thenceforth and forever be called Mount Adams. And so it is.

"Thus closes," wrote Mr. Adams in his diary that night, "blessed be

God, one memorable day of my life."

Unhappily that day was also to be remembered by others, but in bitterness. Toward the end of the Oration, Mr. Adams telling the story of the persecution of Galileo seemed—for the sentence is ambiguous—to say that the Inquisition was the invention of Ignatius Loyola, and then added "To which of the contending causes must the voice of Posterity say—Godspeed? To the champion of truth—and the truth shall ultimately prevail." The next day, Edward D. Mansfield, Whig and Protestant, quoted Mr. Adams in the *Cincinnati Daily Chronicle* to have said: "The Founder of the Inquisition was Ignatius Loyola. . . Moving under the influence of Fanaticism and exciting the imagination, he created a Despotism. . . To which shall we yield? To the Champion of Truth we say, God Speed!" A week later the *Catholic Telegraph,* edited by Father Edward Purcell, brother of the Archbishop of Cincinnati, erupted furiously. It flouted Mr. Adams as "a superlative historian," "an erudite Yankee," and denounced his statement as "a falsehood of the grossest kind," a "monstrous anachronism," since the Inquisition had first appeared three hundred years before Loyola was born.

Before long the partisans were whispering that Mr. Adams had said at the laying of the cornerstone that the Observatory would be "a beacon of true science that should never be obscured by the dark shadows of superstition and intolerance symbolized by the Popish cross." Not one of the newspapers of the day reported any such thing; thirty long years passed before the first statement about it is to be found in print. That Mr. Adams, a tired old man reading in a downpour of rain, should have departed from the manuscript he had written out so painstakingly is unbelievable. Nor is such uncharity in keeping with the blessing on all men he so reverently besought of God. Surely the legend, which has caused so much trouble, is false.

Mr. Adams himself met with kindness everywhere. He tells about meeting a very pretty woman across the river in Covington, who took his hand and whispered, "The first kiss in Kentucky." He admits: "I did not refuse."

The fourth day, on an afternoon glorious in the beauty of a brilliant western sun lighting the town within its semi-circle of hills and Mt. Adams rising nearby, the venerable sage gave his parting blessing to the people thronging the levee, the decks of the boats close at hand, and the windows of the houses overlooking the river. The *Benjamin Franklin No. 6* chugged away upstream, off to Pittsburgh.

Mr. Adams had much overtaxed his physical powers on the trip to Cincinnati.

"I return to my home with the symptoms of speedy dissolution upon me . . .," he wrote on arriving in Washington, "My strength is prostrated beyond anything I have experienced before, even to total im-

potence. I have little life left in me."

He lived five years longer to be stricken down at last on the very floor of Congress, but he never again made an address in public.

II

How did it happen that a President of the United States, a Judge and a Professor should meet at a rendezvous on a hilltop beside the Ohio River. By what roads had John Quincy Adams, Jacob Burnet, and Ormsby MacKnight Mitchel travelled to the dedication ceremonies of the Cincinnati Telescope?

The career of Mr. Adams is written for all to admire in the history of his country. He had seen much of men and events; he had served the people as senator, ambassador, president, lastly as perennial congressman from Massachusetts.

All his life he was a lover of learning, devoted above all in spite of repeated rebuffs to the science of astronomy. In 1823 he had offered a magnificent gift of a thousand dollars to Harvard to build an observatory, but no one else would go along with him. Two years later in his first presidential message he recommended the erection of an observatory "with . . . an astronomer . . . in constant attendance of observation on the phenomena of the heavens." His enemy, John Randolph of Virginia, ridiculed his phrase "lighthouses of the sky" until it became a political catchword. "The rancor of the man's soul against me," said Mr. Adams, "is that which sustains his life." In March, 1840, he had prepared a congressional report urging that the Smithsonian bequest be used to establish an observatory; Van Buren received it with complacency and apparent concurrence, but did nothing at all.

"There is not one study in the whole circle of the sciences," he explained to his constituents in Dedham, just before leaving for Cincinnati, "more useful to the race of man upon earth, or more suited to the dignity of his destination, as a being endowed with reason, and born to immortality, than the science of the stars."

John Quincy Adams, the most distinguished living American, the foremost champion of astronomy, led, as of right, the way to the dedication.

Jacob Burnet, son of the Surgeon General of the Continental Armies born in 1770 at Newark, New Jersey, graduate of Princeton, had come to the frontier post of Fort Washington in 1796 to practice law. Almost at once John Adams appointed him to the Legislative Council of the Northwest Territory. He was leading counsel for Blennerhasset indicted for treason with Aaron Burr. He organized the Miami Exporting Company, served as president of the Bank of Cincinnati that boasted a capital of $600,000, and became president of the Branch Bank of the United States; but he lost his entire fortune in bankruptcy when the Branch closed in 1821, as well as the great house he had built at Third and Vine Streets. Thereafter, undismayed, he went on the Supreme

Court of Ohio, was elected to the Senate of the United States, published his *Notes on the Northwest Territory,* and in 1840 managed the presidential campaign of his beloved friend, William Henry Harrison.

Because he stood head and shoulders above his fellow citizens, Judge Jacob Burnet, President of the Astronomical Society, was chosen to welcome Mr. Adams.

The third had travelled the most briskly of all straight up to Mount Adams. Ormsby MacKnight Mitchel was born on July 28, 1809, in a clearing in the forests of Union County, Kentucky, six miles back from the Ohio, some thirty miles or so below Evansville. His father died four years later, worn out by the hardships of pioneer life. The widow with her brood joined up with a married daughter in the village of Lebanon, Ohio. There little Ormsby studied latin, greek, and arithmetic and joined the Thespian Society. At twelve, they apprenticed him to a store keeper in the village of Miami, thirty miles away. Too proud to brook an unjust charge of telling a lie, he ran away with a train of Conestogas to be a wagoner boy like Tom Corwin.

One day somebody told him that he could get an education free at the United States Military Academy with a salary of twenty-eight dollars a month. So he set out for Sandusky on foot up the old fur traders' trail, guided the last day or so by an Indian boy. He worked his way to Buffalo on a lake steamer, thence down the Erie Canal and the Hudson River. He arrived at West Point on July 1, 1825, in time for the examinations, 27 days before his 16th birthday.

In spite of limited schooling, he stood fifteenth in a class of forty-six, thirteen places below Robert E. Lee of Virginia, two below another Confederate General, Joseph E. Johnston. For two years afterward he taught mathematics at the Point, studying law on the side, engineering on the B & O, courting a lovely widow, Mrs. Louise Clark, who lived at Cornwall six miles down the Hudson. Resigning from the Army on July 30, 1832, he flew like a homing pigeon straight to Cincinnati, bearing a letter of introduction to Judge Burnet.

First he tried practicing law with young Edward D. Mansfield. In a year or so they both quit, Mansfield to edit the *Cronicle,* Mitchel to take a job in the Cincinnati College teaching mathematics and natural philosophy.

During the winter of 1842, the Professor was asked to give three lectures on astronomy in the ballroom of that amazing Bazaar on Third Street, abandoned to her creditors three years before by the even more amazing Mrs. Trollope. The course was announced to be "a grand and noble crusade against the stars," the subject one of dreadful concern to everybody on this earth of ours: "The Stability of the Solar System."

Professor Mitchel had a genius for stating the most "abstruse and sublime truths" with such "glowing eloquence and unexampled per-

spicuity" that any beginner could understand him. He was a devout Christian withal, who did not offend the church people of his day with scientific unbelief. "I have absolute confidence," he told them, "in the wisdom and goodness of God."

Those who were not able to get into the ballroom for the series insisted that he repeat his last lecture in Wesley Chapel. Thus it came to pass that the little Professor saw a vision. Suddenly at the end of his talk, he told the two thousand or so cheering him that he was resolved to devote five years to the erection of a great astronomical observatory right here in the City of Cincinnati.

He had not a penny in his pocket, no future prospects whatever, except his fifteen hundred a year for teaching; he had little influence, political or social—no potentate, prince or plutocrat to back him. But he who had set out at fifteen with twenty-five cents to walk a thousand miles and had landed at West Point with the same shilling in his pocket was not one who in his vigorous manhood would fear the impossible.

"I will go to the people," he said, "and by the anvil of the blacksmith, by the work bench of the carpenter, and thus onward to the rich parlor of the wealthy, I will plead the cause of science . . . I shall visit personally one thousand of our citizens and be refused by each and everyone before I will yield and resign the effort. I am determined to show the autocrat of all the Russias that an obscure individual in this wilderness city in a republican country can raise here more money by voluntary gift in behalf of science than his majesty can raise in the same way throughout his whole dominions."

And *that* he did.

On May 23, 1842, within a month, a public meeting was held, Judge Burnet presiding, to organize the Cincinnati Astronomical Society. Subscriptions of $6,500 at the rate of twenty-five dollars per share were announced. They came from no particular class or order of men, but from the whole people of all degrees of wealth, of sixty-seven different professions and vocations, banded together: thirty-nine wholesale grocers; thirty-four persons living from rents; thirty-three lawyers and six judges; thirty drygoods merchants; sixteen druggists; eight blacksmiths; seven paperhangers; five steamboat owners; three livery-stable keepers; three stonemasons; three butchers; two lamp dealers; two plumbers; one brick-maker; and so on.

Ten days later, the Board of Control voted to send Mitchel to Europe at once. They gave him a thousand dollars and saw him off on the stagecoach. On the fourth day he was roaring down the B & O at 20 miles per hour, into Washington.

He hoped that the government might accredit him with an official mission, but Daniel Webster, Secretary of State, highhatted him, while the President, Van Buren, received him, as he reported, "in a peculiarly droll and facetious manner." He turned with feelings of the greatest

respect to John Quincy Adams. Alas, Mr. Adams wrote that evening in his diary: "There is an obtrusiveness of braggart vanity about the man which he passes off for scientific enthusiasm and which is very annoying." Perhaps the august New Englander who had been kept in stalemate so long was a bit peevish that a little Westerner was on his way to win the game; perhaps also, Professor Mitchel was a bit above himself.

The passage to London on the *David Garrick* of the Dramatic line, bedeviled by calms or head winds, took two months. There was not in all of England, however, a lens worthy of the Cincinnati Astronomical Society. Nor would Cauchoix in Paris promise anything within three or four years. But at the Frauenhofen Institute in Munich, Mitchel found an objective for a refracting telescope made of two lenses, one double-convex of crown glass, the other concave-convex of flint glass, juxtaposed but not cemented, gigantic, twelve inches in diameter, achromatic, ground to an unbelievable precision, mystic, wonderful.

"This was the glass in search of which I had traversed the ocean and the land," said Mitchel exulting. "Its magnitude and powers were beyond anything I had dared to hope or anticipate."

The price—nine thousand dollars—was also far and away beyond any authority granted to Mitchel, but no mortal being could withstand such temptation. He ordered it conditionally and they promised not to let anybody else have it, for a while at least.

He headed for home on the dead run to put the question up to the Astronomical Society; would it buy the greatest refractor in the world? The members expressed their willingness if he would raise the money. Before the second week in November ended, he collected $2,000 and sent 420 pounds, 11 shillings and threepence, through Baring Bros. of London, to seal the bargain. Then, then only, did he stop to take a long deep breath of air.

During that winter he fixed his eye on the southeast bastion of the arc of hills that surrounds the basin of the city. Twenty-five acres planted in vineyards, running down the southern slopes where the sun shone warmest, belonged to Nicholas Longworth, the largest owner of land in the country next to John Jacob Astor. The five acres at the summit, four hundred and fifty feet above the level below, afforded a perfect horizon in every direction. To the east and south the eye fell into a narrow chasm gouged out of the stubborn clays of the Silesian uplift by glacial floods where the Little Miami Railroad ran along the river bank, exchanging freight with crowded rows of steamboats. Over across lay the green Kentucky hills, cut in two by the valley of the Licking all dotted over with good looking farm houses. The suburban towns of Newport and Covington stretched westwardly on the southern shore; downstream the eye travelled mile on mile along the Ohio. On the west at the foot of the hill, Cincinnati with its schools, churches, its

trim red-brick homes, its slaughter houses, distilleries, and foundries, rested on the level between the silver line of the Miami and Erie Canal and the Ohio. Beyond, the Millcreek Vally under the western uplands seemed like a garden spot. To the north stood first Mt. Auburn, a lovely tree covered village, then the garden of Eden, all clad in green vineyards and orchards or gorgeous in autumn livery.

And then on that hilltop, Ormsby MacKnight Mitchel, pursuing his destined course, joined with Mr. Adams and Judge Burnet.

A Simple Account of Relativity

By W. CARL RUFUS

The tests of relativity belong to the field of astronomy; so during the past twenty-five years, the subject has been presented many times to my undergraduate students. The interest extended beyond the classroom and I was assigned the subject as given above for a popular or semi-popular lecture, which has been repeated in different form on several occasions.

The relativity here considered is not the relativity of knowledge, *i.e.*, the philosophical doctrine that the mind of man can know only the subjective effect produced by objects of the physical universe. It is not the relativity of sensations, awareness, and consciousness, *i.e.*, our psychological responses to physiological stimuli. It is not relativity of values in the ethical realm, nor of right and wrong in religion.

What then is the kind of relativity subjected to astronomical tests? The principle of relativity here considered lies entirely within the physical realm, although it may have pertinent philosophical and other implications. Limiting it more precisely within its own sphere, relativity should not be confused with relative motion. Ancient Greek philosophers were acquainted with that idea; Copernicus applied it in his heliocentric system of the motions of the heavenly bodies; and Newton incorporated it in the classical dynamics of the material universe, based on his law of gravitation.

The Greeks attacked the problem of celestial motions *relative* to a stationary earth: Kepler formulated his laws of planetary motion *relative* to the sun. In the two-body problem using Newtonian gravitation, motion is determined *relative* to the center of mass of the system. In this sense of relative motion, the moon revolves about the earth, the earth revolves about the sun; the sun moves in our galactic system toward the constellation Hercules; our galactic system is moving at a rapid speed *relative* to extra-galactic systems or the metagalaxy. Thus the motion of the moon becomes increasingly complicated.

A search for a final frame of reference for absolute motion led to interesting results. After Römer discovered the finite velocity of light

and determined its approximate value, a hypothetical medium for its propagation was postulated, the "luminiferous ether." Endowed with properties, some of which appeared contradictory, this medium served science quite adequately to explain the chief phenomena associated with the wave theory of light. Was the ether merely a mental product or did it exist by its own right in the physical sense? If it had physical content, it would provide a basis for a final frame of reference for absolute motion.

The important Michelson-Morley test was applied in 1887. The earth is moving about the sun with a velocity of 18½ miles per second or about one ten-thousandth the velocity of light, a quantity easily measurable. But the measured velocity of light in the direction of the earth's motion, opposite that direction, and at right angles to it, showed no difference. This null effect, some thought, might be due to "ether drag," the earth pushing or pulling it along. This, however, was inconsistent with the aberration of light. So to harmonize the results the Fitzgerald-Lorentz contraction theory was adopted:—all matter, including the measuring-rod, contracted in the direction of motion in the ratio $1 : \sqrt{1 - (v^2/c^2)}$ where v is the velocity of the observer relative to the sun in this case and c is the velocity of light which became a universal constant.

The null effect led to the conclusion that absolute motion cannot be found by any experiment whatever. It also led to a more startling conclusion, that no absolute standard of time and space measurement can be found. In 1905 Einstein held that absolute space and absolute time are products of the mind and not derivable from observations and experiments. Minkowski in 1908 welded these two mind products into one when he stated: "Henceforth, time by itself and space by itself are mere shadows, they are only two aspects of a one and inseparable method of coordinating the facts of the physical world."

So the theory of relativity of modern physics deals with systems of coordinates or what amounts to the same thing it deals with our methods of measurement. The astronomer has adequate time and space to explore so his aid was solicited.

Another introductory word is necessary regarding coordinates or measurements. In a plane we fix two straight lines usually at right angles for a frame of reference. Two measurements are necessary and sufficient to define the position of a point in that plane. The graph of a point moving in the plane in a stright line, a circle, or according to other conditions may be expressed mathematically. In space of three dimensions after fixing a frame of reference three measurements are required usually labeled x, y, and z. In the space-time continuum, four coordinates are necessary, three space measurements and one time measurement, x, y, z, and t.

We must also introduce the transformation of coordinates. If we

refer our measurements in a plane to a new pair of straight lines we may do so very easily by applying simple transformation formulas. In space the formulas are a little more complicated and in the four-dimensional system they become quite complex. In the plane these formulas and their application must be consistent with the laws of plane geometry, trigonometry, and analytics. Similarly in space they must conform to the laws that apply in solid geometry, trigonometry, and analytics. An analogous condition must be imposed in a four-dimensional space-time system. In a mathematical sense, then, these transformation coordinates condition the space-time continuum through which the transformation takes place.

Now Einstein enters. He assumes that the laws of nature analytically expressed must remain invariant for any transformation of coordinates. Or to put it in simple form, if a mathematical expression in one set of coordinates in a plane represents a straight line and a transformation is made to a new system of coordinates the line must remain straight. That seems very reasonable; we would suspect something was wrong if it came out crooked. So the transformation formulas in the space-time system that keep the laws of nature unchanged become very significant: *they condition the space-time continuum* in which the frames of reference are fixed.

Perhaps this may be expressed in another way. Two astronomers observe the same physical event, *e.g.,* the approach and the recession of a comet. Science demands agreement (within the probable error of measurement) in the results obtained from the observations and reductions of the two men, though they were stationed on opposite sides of the earth and observed at different times, even if they referred their data to different sets of coordinates, *e.g.,* geocentric and heliocentric.

From the transformation formulas are drawn some remarkable conclusions. One is a new law of gravitation, which includes Newton's law in terms of the first order plus some higher-order terms of very small magnitude. Newton's law is not rescinded, it is very slightly amended.

The "equivalence principle" is interesting. It states that a uniform gravitational field of intensity g is equivalent to the effect of motion with acceleration g. And it follows conclusively, since no final frame of reference can be found, that the effect of gravitation can not be distinguished from that of acceleration. This may be illustrated by a ride in an elevator car. At rest a body in the car has weight ($w = mg$) and force is required to hold it from falling. When the car is descending with accelerated motion (acceleration $= g$) the same body in the moving system has no weight and needs no support to keep it from falling to the bottom of the car.

Another interesting result is that mass in motion is greater than mass at rest according to the following relation:

$$\text{Mass in motion} = \frac{\text{mass at rest}}{\sqrt{1 - (v^2/c^2)}}.$$

This has been verified in the case of high-speed electrons, some of which have acquired a velocity by means of the cyclotron as great as 9/10 the velocity of light. Their mass is then twice the rest mass. From the relationship just given it becomes evident that v can not equal c or the moving mass would become infinite, a physical impossibility, so c, the velocity of light, is the maximum speed attainable in the physical universe according to relativity.

The mass-energy equivalence may also be derived and here is where light comes within the realm of gravitation. In Maxwell's electromagnetic theory of light

$$M = E/c$$

but by ordinary mechanics

$$M = mc,$$

(M is momentum, E is energy, and m is mass). Eliminating M, we have $E = mc^2$. Putting in the value c, we find that the energy for one gram mass is 9×10^{20} ergs. This has also been demonstrated in the laboratory in connection with transformations of atomic nuclei.

We have seen that the law of gravitation is slightly changed quantitatively by relativity, but our idea regarding the nature of gravitation has been completely revolutionized. Newton, of course, did not discover gravitation, he merely formulated the law of gravitation. He did not find out what it is, but how it acts. He admitted, "I have not been able to discover the cause of those properties of gravity from phenomena, and I frame no hypothesis." In classical mechanics gravitation appeared like a force exerted by mass. In the mechanics of relativity it appears like a property of the space-time system in the presence of mass. In other words, though I don't like the expression, space-time is warped by a gravitational field. I don't like it because it is so easy to give the idea that space alone is warped or curved.

But to return to the law of gravitation. The quantitative expression for the law is a necessary consequence of our metric system, *i.e.*, it follows analytically from our scientific methods of measurement. And we mean the ordinary daily routine measurements by physicists and astronomers in the objective, physical universe, in which we live and move and have our being. That may seem more realistic than the warping of space-time or the idea that gravitation is a continual attempt of space-time to straighten itself. Why should it want to be straight? Shall we endow our brain child with ethical qualities also? Fitzgerald didn't go that far when he said in 1894, "Gravity is probably due to a change in structure of the aether produced by the presence of matter."

Now let us turn to the three astronomical tests of relativity proposed by Einstein.

1. *The motion of the perihelion of Mercury's orbit.* Observations give 574″ per century for the change of longitude, but that is 40″ per century in excess of the advance computed on the basis of Newton's law of gravitation. Leverrier of Paris first noted this excess and suggested that it might be caused by an undiscovered intra-Mercurial planet. Search was made at the time of a solar eclipse and an obliging Frenchman, Lescarbault, announced its discovery in 1859. Leverrier named it Vulcan. Watson, second director of the Observatory of the University of Michigan, surpassed the French astronomer and announced the discovery of two intra-Mercurial planets in 1878. Neither has since been seen. Search by efficient photographic methods has failed to find a body within the orbit of Mercury to account for the excess motion.

Other causes have been sought. Intra-Mercurial meteoric matter and finely divided particles have been proposed, like the material that causes the zodiacal light. But a sufficient amount would give more reflected and scattered sunlight than is observed and would raise a problem regarding transparency. An oblate sun would produce an effect in the right sense, but its oblateness, if any at all, is too small.

The Einstein excess over Newtonian is $360°\,(3v^2/c^2)$ per revolution, which amounts to about 43″ per century and satisfactorily solves the long-standing problem.

2. *The deflection of a ray of light by a gravitational field.* Einstein proposed that this test be made at the time of a total solar eclipse on the positions of stars. The amount of the deflection at the sun's limb due to the mass of the sun is 1″.75. It had not previously been observed. Einstein said in effect, "Look for it and you will find it." Two English eclipse parties responded in 1919 and announced that they had obtained results in accord with the Einstein deflection. Conditions were not entirely favorable, so many scientists awaited further evidence. It came in 1922 when observers from Lick Observatory, with better equipment and excellent conditions, obtained plates showing 550 star images. Comparing positions on photographs with others made of the same star field when the sun was far away gave data for the test. The final report gave the adjusted mean of the observed deflections as $1''.75 \pm 0.09$. Canadian observers also announced that they had "proved" the effect.

3. *The displacement of spectrum lines by a gravitational field.* This might be tested in the case of the sun. Radiant energy emerging from the sun is decreased by the gravitational backward pull. The energy of escape is equal to $h\nu\,[1 - (\phi/c^2)]$. (h is Planck's constant, ν, the frequency of the radiation and ϕ the gravitational potential.) The decrease of energy or lower frequency gives a displacement of spectrum lines toward the red equivalent to a Doppler effect of 0.634 km/sec. This value is, of course, large compared with measurable displacements. But there are many difficulties involved. Other causes of displacements

are numerous and their effects are all superposed in the ordinary solar spectrum. The problem was attacked at Mt. Wilson and the first announcement indicated a displacement in the right direction but only about one-half the required amount. A more intensive program was carried out, after careful laboratory study of the selected lines, and the results confirmed the test.

Another opportunity to make this test was afforded by the white dwarf companion of Sirius. It has stellar mass, but planetary dimensions, so the density is very great, estimated to be 50,000 times that of water. Consequently, the gravitational field at its surface is very great and the Einstein displacement of spectrum lines is of the order of 20 km/sec. Adams at Mt. Wilson and Moore at Lick found displacements in accord with the required amount.

So the three proposed astronomical tests have apparently been satisfactorily met, which seems to give relativity a good scientific status, at least as a useful working theory.

If relativity is established, then what? As Jeans says: "Space means nothing apart from our perception of objects and time means nothing apart from our experience of events." What remains absolute for the scientist? In the first place the constant velocity of light is assumed. As Brownell puts it: "Light becomes the standard and the test of motion; and the pure speed of light measures other motions and the world of space and time." Number remains with its endless extension. Planck's unit of action abides ($h = 6.56 \times 10^{-27}$ erg sec), energy multiplied by time, the least amount of work that can be done, indispensible in computing action within an atom absorbing or emitting radiation. The increase of entropy, which is the sum total of unavailable energy, as the available supply runs down, also appears to remain and to be irreversible like the turning back of time in human affairs.

A scientist may philosophize with temerity, but occasionally he enjoys "blowing bubbles" in his own back-yard. Their effervescence helps to relieve the strain of sustained objectivity.

Relativity provides a pathway from mind to matter. A reasonable assumption is made regarding the method of coordinating events in the physical universe. Measurements must be made in such a way that two observers using different frames of reference will not violate the laws of nature when they compare results. To keep the spirit of the assumption mathematical relationships are imposed. Operating with these brain products according to logical methods a conclusion is reached regarding the material universe. Consistency and harmony have been achieved in the realm of mind. And what follows?

Based on these mental operations come specific verifiable facts regarding the objective universe. Go out there and you will observe what you did not know—light is bent precisely so much by a gravitational field. Go out there again and you will see what you did not

know—lines of the spectrum are displaced just so much, no more, no less, by a gravitational field. And lo, it was so!

The inquiring mind, that is eager to know the why as well as the how, has the right to philosophize regarding this intimate relation. Space and time were once considered separate entities. Now space-time is a single concept, a concept derived from the collective experience of humanity. A mental product. Mass and energy were considered two separate entities non-transformable, now they are convertible at the will of man. Are they merely mental products also? Or do they exist in their own right regardless of the mind of man? If the human mind can create space and time, is it possible that a Superior Mind, a Supreme Intelligence, could create mass and energy, the physical universe?

In a philosophic mood looking at the method of the scientist we see that he frequently makes hypotheses, like the nebular hypothesis or the planetesimal theory, to rationalize a set of related facts, observations, and experiences. The assumption of a Supreme Intelligence seems quite necessary to rationalize the relationship between mind and matter brought into the open so clearly by relativity and to answer some of the scientific questions that arise in its wide application.

Milne of Oxford University near the end of his book on Relativity turns philosopher and religionist. He ventures to state: "One can say, if one pleases, that we have found God in the universe. For the universe seems to be a perfect expression of those extra-temporal, extra-spatial attributes, we should like to associate with the nature of God." We venture to add that God is not merely beyond space and time, but He is also within mind and matter, harmonizing, unifying, and rationalizing the problems of science, philosophy, and religion.

OBSERVATORY OF THE UNIVERSITY OF MICHIGAN, SEPTEMBER 1, 1943.

Sunspots in 1769 and in 1943

By H. B. RUMRILL

The recent fine sunspot afforded a good opportunity for testing some of the ideas propounded in "Observations of the Solar Spots, by Alexander Wilson, M.D., Professor of Practical Astronomy in the University of Glasgow," published in the *Philosophical Transactions* as having been "redde" April 29, 1773.

Professor Wilson's conviction that the spots are depressions or excavations in the luminous matter of the sun, as based on his observations of the spot of November-December, 1769, has not lacked confirmation and is referred to in many of the astronomical books. He worked with a Gregorian reflector magnifying 112 times and acknowledged surprise at the phenomena depicted in his drawings. The term photosphere was not in use then, and what we know as the umbra and penumbra are referred to by him as the nucleus and umbra, respective-

ly, the word nucleus now being taken to represent the internal structure of the umbra.

While engaged in observing and sketching the recent spot I received from London a copy of Wilson's paper as originally published, and took occasion to study his work in its entirety, and make a comparison of his drawings with my own. Now, this last important spot conveyed to my eye a very definite appearance of a depression in the photosphere, but not accompanied by any such appearance of the penumbra as seen by Wilson in positions near both the eastern and western limbs. It was at the western limb that he first noticed the peculiar effect that occasioned the writing of his paper, repeated in reverse near the eastern limb at the reappearance of the spot. From the well-known effects of "foreshortening" it would seem to be impossible for the penumbra to be seen either east or west of a spot when close to the limb, and I cannot recall any such appearance, although as a spot comes into fuller view with the sun's rotation the penumbra may be perceived all around the umbra, but with a greater extension to the north and the south.

In connection with the phenomena of spot depressions it may be of interest to repeat from the remarks of Asaph Hall concerning his observations of Mars in 1892 (*Astronomical Journal,* No. 288, February 8, 1893), with regard to the south polar spot, that

> During the last part of the observations, when the spot had become small, the center had the appearance of a depression or cavity in the surface of the planet. This may have been only a subjective phenomenon depending on the observer; but my experience was the same in 1877.

I first observed the spot shortly after 8:00 o'clock in the morning of September 26, when the umbra was about 10 seconds from the eastern limb, showing the penumbral fringe only to the north and the south. On September 27, twenty-four hours later, the penumbra was visible all around the umbra, broader north-south than east-west, and on September 28, at 11:00 A.M., there was little difference in the width of the penumbra. Except for the development of a division of the spot into two lobes on October 2 (a similar phenomenon having been observed by Professor Wilson on October 8, 1770), the spot remained nearly constant in general appearance throughout its seeming passage over the disc, until its close approach to the western limb on the morning of October 9—very like its appearance when first seen—and it was just at the limb at 1:30 P.M. of that date. The division of the spot was probably a photospheric effect, as it was less marked the following day and thereafter, and this may have also been the case with the same phenomenon as noticed and drawn by Wilson. (This spot reappeared at the eastern limb on October 24 and again on November 20.)

The magnifying power I have used is mostly 76, sometimes 61 and 150, the latter generally for verification of the exceedingly minute spots that frequently appear in extended groups. The aperture of my telescope is four inches; that of Professor Wilson's is not mentioned.

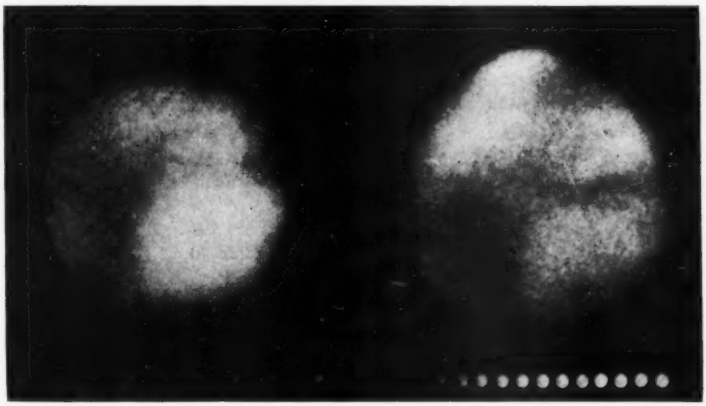
Alexander Wilson was born in 1714 and died October 18, 1786, when Sir William Herschel was at the zenith of his career.

TREDYFFRIN OBSERVATORY, BERWYN, PENNSYLVANIA, OCTOBER 18, 1943.

Mars in 1943 and 1939

By LATIMER J. WILSON

The 1943 apparition of Mars was particularly interesting because it afforded an opportunity to compare the surface features with those of 1939 at a time when the seasons of Mars were almost opposite, while the inclination of the planet's pole toward the earth was almost identical. The dates of observations selected for comparison were: 1943, November 29, $3^h\ 40^m$ U.T., central meridian, 314.84; 1939, August 18, $4^h\ 38^m$, U.T. central meridian, 317.05. The heliocentric longitude for these dates were approximately 341 for 1943, and 227 for 1939.



PHOTOGRAPHS OF MARS THROUGH 12-INCH REFLECTOR

At the left is a row of miniature images, four of which were superimposed to furnish the enlarged image above. November 29, 1943. Southern pole inclined 6.03 degrees toward earth.

At right: a row of images secured August 18, 1939. One image was used to furnish the enlargement. The southern pole, surmounted by the melting snow cap, is inclined 6.17 degrees toward earth. South is at the top in both photographs.

According to Pickering's Martian Calendar, POPULAR ASTRONOMY, October, 1915, these heliocentric longitudes correspond to the Martian date of Februay 21, or March 1, terrestrial date, for 1943; and November 1, Martian date, or November 9, terrestrial date, for 1939. Therefore the southern hemisphere of Mars was entering the final days of its summer season, and the southern polar cap had vanished, on this date in 1943. The southern hemisphere in 1939 was passing through

mid-spring in 1939, and the south polar cap was rapidly diminishing in size.

It is interesting to compare the photographs of the disks which suggest these seasonal changes. At the time they were secured Mars was about 11,179,440 miles farther away in 1943 than in 1939. The greatly enlarged images are not made to exact scale, for the miniature originals were differently enlarged in the telescope to take advantage of conditions of seeing. The seeing in 1939 was much better than in 1943, and larger images could be secured accordingly. All exposures were about 1/10th of a second duration. In 1939 an orange filter was used, but no filter was used in 1943. In the photographs, a single image was enlarged to present this view of the planet, August 18, 1939. It was necessary to superimpose four of the best images of those secured November 29, 1943, to obtain about the same degree of contrast.

The Planets in March, 1944

By WILLIAM A. CALDER

NOTE: Greenwich Civil Time is used unless otherwise stated. To obtain Eastern War Time, subtract 4 hours; Central War Time, 5 hours, etc. The information is taken from the *American Ephemeris and Nautical Almanac*.

Sun. The sun passes from its position of March 1 at $\alpha = 22^h\ 47^m$, $\delta = -7°\ 42'.6$ (in Aquarius) to $\alpha = 0^h\ 41^m$, $\delta = 4°\ 24'.6$ (in Pisces). On March 20 at $17^h\ 49^m$, the sun's center crosses the equator and spring begins in the northern hemisphere.

Moon. The phases of the moon are:

		h	m
First Quarter	March 1	20	40
Full Moon	10	0	28
Last Quarter	17	20	5
New Moon	24	11	36

The moon is in apogee on March 8, 7^h when its distance from the earth is 252,400 miles. It is in perigee on March 23, 10^h, at a distance of 223,000 miles.

Mercury. Mercury is difficult to observe telescopically because of its proximity to the sun. On March 17, 21^h it is at superior conjunction. Thereafter, until May 2, it is an evening star.

Venus. Venus continues to be a morning object, but is continually advancing toward the sun. On the first of the month it is of magnitude —3.4, and .86 of its disk is illuminated, as we view it. At the end of the month it has decreased but a tenth of a magnitude in brightness, for, although it is more distant, .92 of its disk is visible.

Mars. Mars and Saturn are both moving eastward, just south of Auriga. On March 7, 15^h Mars passes Saturn, but Mars is 3° 15′ north of Saturn. The apparent diameter and magnitude of Mars are 8″.0 and 0.6 on March 1, and 6″.3 and 1″.2 on April 1, respectively.

Jupiter. The giant of the planets is the chief object of telescopic interest in March. It is practically as large in apparent diameter as it was at its recent opposition, and more convenient to observe because it is higher in the sky in early evening. It would be possible to witness a whole rotation of the planet

during a single night, since the day of Jupiter is equal in length to about 9 hours and 55 minutes. If this should seem a bit tedious, one can see the whole of Jupiter by looking at it on two successive nights, making the observation an hour later on the second night. Jupiter will have made two and a half turns in the twenty-five hours. When making a careful study of the markings, however, it is necessary to confine one's attention to features near the center of the disk. Effects of foreshortening, darkening, and poor definition give incorrect impressions of details toward the limb of the planet. The limb darkening is much more noticeable in red light than in blue (the reverse being true of the sun). It would be interesting to observe an occultation of Jupiter, observing the first contact with a blue filter and then rapidly switching to a red filter to see the first contact of the apparently smaller planet in red light. Such an attempt was made at the occultation of January 13, but a thin haze prevented conclusive results.

For many observers, the satellites of Jupiter possess even greater attractions than the whirling cloud-ball itself. Upon the whole, the most interesting thing for the amateur to watch is the passage of the tiny shadows of the moons across the disk of Jupiter. After opposition (as a present) the shadows follow the satellites, and when a satellite emerges from behind the disk of the planet, it is invisible for a time because it is in the shadow of Jupiter. The apparent motion of the moons and their shadows when transiting the planet is from right to left, as seen in an inverting telescope.

There is nearly always something of interest going on in the Jupiter family. Events which can be seen from the western hemisphere on six nights in March are listed below, as taken from the *American Ephemeris*. It must be remembered that these will take place after midnight at Greenwich, and before midnight (for the most part) in America, and hence are listed a day later by the calendar of Greenwich than will take place in America. For example, the first phenomenon listed will be seen on March 3 at 7:53.9 P.M., Central War Time.

G.C.T.	h m	Event	G.C.T.	h m	Event
Mar. 4	0 53.9	II. Ec. R.	Mar. 14	2 29	III. Tr. I.
	2 43	I. Tr. I.		5 24	III. Sh. I.
	3 13	I. Sh. I.		6 4	III. Tr. E.
	5 0	I. Tr. E.		8 59	III. Sh. E.
	5 30	I. Sh. E.			
	6 41	IV. Oc. D.			
18	1 36	II. Oc. D.	20	0 28	II. Sh. E.
	6 2.9	II. Ec. R.		0 42	I. Tr. I.
	6 15	I. Tr. I.		1 31	I. Sh. I.
	7 2	I. Sh. I.		2 58	I. Tr. E.
	8 32	I. Tr. E.		3 48	I. Sh. E.
25	2 49.4	III. Ec. R.	27	0 11	II. Sh. I.
	3 56	II. Oc. D.		1 9	II. Tr. E.
	8 2	I. Tr. I.		2 29	I. Tr. I.
	8 37.4	II. Ec. R.		3 5	II. Sh. E.
				3 25	I. Sh. I.
				4 46	I. Tr. E.
				5 42	I. Sh. E.

The Roman numeral refers to the satellite involved. I. denotes ingress; E., egress; D., disappearance; R., reappearance; Ec., eclipse; Oc., occultation; Tr., transit of the satellite; Sh., transit of the shadow.

Saturn. Saturn is moving slowly eastward just south of Beta Tauri. Its apparent magnitude is about 0.2 during the month. Saturn and Jupiter have always

been close rivals in exciting the imagination and admiration of observing astronomers. For many years, these planets tied in having nine known satellites. A half dozen years ago, Nicholson discovered two more tiny moons of Jupiter. Now comes word that Saturn can boast of a moon with an atmosphere. This should surely equal the importance of Jupiter's tenth and eleventh moons that are so small that they would require a six-inch telescope to be seen by an observer on Jupiter itself! It will perhaps be found that some of Jupiter's moons also have atmosphere, inasmuch as they are larger than Titan.

Uranus. Uranus is not far from ω Tauri, and can easily be located by referring to the chart of its path for 1944, in the January issue of POPULAR ASTRONOMY.

Neptune. Neptune is in opposition with the sun on March 23, when its distance from the earth is about 2,720 million miles. It will be found very near η Virginis.

Occultation Predictions for March, 1944

(Taken from the *American Ephemeris*)

Date 1944	Star	Mag.	IMMERSION Greenwich C.T.	IMMERSION a	IMMERSION b	IMMERSION Angle E from N	EMERSION Greenwich C.T.	EMERSION a	EMERSION b	EMERSION Angle E from N
			h m	m	m	°	h m	m	m	°
	OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′									
Mar. 3	BD+19°1110	6.0	4 31.8	—1.0	+0.2	47	5 18.0	+0.3	—2.8	316
3	57 Orio	5.9	5 40.0	—0.2	—0.9	73	6 35.1	+0.4	—1.7	290
4	61 Gemi	5.9	22 2.1	..	..	22	22 34.5	..	..	333
6	θ Canc	5.6	6 49.5	—0.4	—1.8	113	7 52.9	—0.1	—1.6	279
15	γ Libr	4.0	6 24.9	—2.1	+2.0	70	7 20.9	—0.6	—1.5	340
31	16 Gemi	6.1	3 57.6	—0.8	+0.1	46	4 37.6	+0.6	—2.8	324
31	ν Gemi	4.1	4 20.3	0.0	—1.7	111	5 15.6	+0.1	—1.0	259
	OCCULTATIONS VISIBLE IN LONGITUDE +91° 0′, LATITUDE +40° 0′									
Mar. 3	BD+19°1110	6.0	4 9.1	—1.4	—0.5	74	5 20.4	—0.7	—0.2	288
3	57 Orio	5.9	5 35.1	—0.6	—1.4	98	6 40.1	—0.3	—1.2	266
6	θ Canc	5.6	6 46.1	—0.5	—2.8	142	7 46.1	—1.2	—0.9	253
15	γ Libr	4.0	5 58.1	—0.7	+0.9	104	7 7.1	—0.9	0.0	304
15	η Libr	5.6	11 49.3	—1.9	—0.9	99	13 10.9	—1.5	—1.8	294
19	253 B.Sgtr	6.0	11 37.4	—1.7	+1.0	86	12 57.5	—1.9	+0.3	271
27	μ Ceti	4.4	1 43.5	—0.2	—2.3	118	2 25.4	—0.3	+0.8	211
31	16 Gemi	6.1	3 41.4	—1.1	—0.8	77	4 46.4	—0.2	—2.0	294
31	ν Gemi	4.1	4 25.9	0.0	—2.9	140	5 12.4	—0.8	0.0	231
	OCCULTATIONS VISIBLE IN LONGITUDE +120° 0′, LATITUDE +36° 0′									
Mar. 2	m Taur	5.0	8 17.1	—0.4	+0.1	51	9 2.7	+0.6	—2.0	305
3	BD+19°1110	6.0	3 11.4	—2.4	—0.3	94	4 43.5	—2.2	0.0	255
3	57 Orio	5.9	5 14.2	—1.4	—3.5	137	6 11.5	—2.1	+1.5	222
14	13 Libr	5.8	11 9.3	—2.8	+0.5	80	12 22.3	—1.4	—2.4	333
15	η Libr	5.6	10 58.0	—1.4	—1.1	140	12 18.2	—2.5	—0.1	270
19	253 B.Sgtr	6.0	11 6.3	—0.2	+0.2	122	12 4.1	—1.3	+1.7	245
31	16 Gemi	6.1	2 59.1	—2.1	—1.6	112	4 22.5	—2.0	—0.2	252

The quantities in the columns a and b are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under a for the star to be observed; similarly,

with the latitude, using b; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

The days 20 to 28 of October, 1936, were either very prolific of fireballs or observers much more attentive than usual. The paths of one fireball on October 21 seen from here at 8:25 P.M., were worked out by Donald A. MacRae then of our staff, and published in POPULAR ASTRONOMY, **50**, 500, 1942. On page 551 of that same volume was a brief description by me of the Illinois-Michigan fireball of October 28. The second fireball of October 21, which came at 10:29 P.M., will now be discussed.

This object was fully observed and its path mapped by P. H. Taylor, then on our staff. He saw all of the path except the very end, this being hidden by trees. He was at Flower Observatory, S1. Dr. D. C. Dearborn of Catawba College, Salisbury, North Carolina, who was 10 miles to the southeast at the moment, S2, and two of his students also sent in a full description, with measured coordinates. This reached me through Dr. M. L. Braun, our regional director in North Carolina. Another observation by Mr. and Mrs. D. M. Yoder of Philadelphia, S6, checks Taylor's, though exact coordinates were not given. E. W. Kuester of Baltimore, S5, also gave approximate azimuths in his report. Miss H. L. Frefers, Barnesboro, Pennsylvania, S4, observed it to start in the north and travel across the northwestern horizon. A report from S. K. Lichty at a place $\lambda = 78° 40'$ W, $\phi = 41° 02'$ N, S3, gave the path as perpendicular to the horizon and to the S.E., the fireball disappearing behind a hill. As the inference is that he was driving and in unfamiliar country, if he meant S.W., the observation would fit in exactly, as the adopted path is perpendicular from S3. With these data no special difficulty was anticipated in a solution.

However, study showed inconsistency in the *reported* coordinates at S2 and the accompanying description of the path. I quote from the S2 report to make clear the difficulty and to justify the changes I made in the data from S2 and also the essential parts of S1. S2 . . . "at 10:27 P.M. . . . a rather bright meteor, first showing itself about 10° above the horizon and slightly to the left of α Urs. Maj. . . travelled almost horizontally, slightly downward rather than upward, leaving a yellow to white trail which when under the bowl of the Little Dipper became decidedly brighter and of a greenish color. This was about 2/3 of the distance of its flight. The green part . . . lasted about 30 seconds, whereas the other part was quickly extinguished. . . The green section . . . was appreciably greater in width and area than the earlier white portion. The coordinates were estimated as follows: Start $\alpha = 11^h 30^m$, $\delta = +62°$; change to green $\alpha = 14^h 40^m$, $\delta = 68°$; end $\alpha = 16^h 20^m$, $\delta = +66°$ . . ."

At S1, Taylor described the object as very variable in magnitude, only +2 when first seen, —2 at brightest, 0 magnitude at end; color blue; duration 5

seconds, duration of train 5 seconds. That the train was seen for so much shorter a time at S1 than at S2 is due to the fact that our sky is never free from lights, etc., while S2 was in the open country. All the other observers make it much brighter than described by Taylor. The usual data for him follow: It began at $\alpha = 284°.1$, $\delta = +34°.2$; greatly brightened at a point $\alpha = 283°.8$, $\delta = +17°.2$; last seen (not end as trees interfered) at $\alpha = 283°.6$, $\delta = +6°.0$. One notes the positive statement at S2 that the meteor traveled west "almost horizontally, slightly downward rather than upward" and that it "started slightly to left of α Urs. Maj." But the coordinates given, when turned into altitude and azimuths, give for the former 8°, 17°, and 22°, respectively! It must be remembered that the stars used for comparison, for $\phi = 35°.6$ N, were *very low* in the north and easy to misidentify, particularly one so faint as α Draconis. Yet nobody could mistake a path sloping down for one slowing upwards. In my solution I have therefore kept the beginning azimuth point for S2 without change, but used altitudes of 10°, 9°, and 8°, respectively, for the first point seen, the 2/3 point, and the end. I may add that an error of exactly 2 hours in computing sidereal time, using our map I and laying off the horizon thereon for S2, would fully explain the erroneous coordinates, and I assume this error was made. I added 5° to Taylor's path as he did not see the end. By these procedures, I secured a path based on S1 and S4 for the real beginning point; on S2 for first point on path seen from there; on S1 and S2 for point of great increase in light; on S1 and S2 for end point. These four points lie almost on a straight line and hence confirm my opinion that my procedure was reasonable and probably correct.

Date	1936 October 21/22, 10:29 P.M., E.S.T.
Sidereal time at end point	1°.0
Began over	$\lambda = 78°\ 45'$ W, $\phi = 41°\ 00'$ at 147 km
Ended over	$\lambda = 81°\ 37'$ W, $\phi = 39°\ 12'$ at 77 ± 5 km
Length of path	324 km
Projected length of path	317 km
Observed velocity	54 km/sec (most uncertain)
Height of longest-enduring point in train	92 km
Radiant (uncorrected)	a = 231°, h = 11°.2—
Zenith correction	—0°.6+
Radiant (corrected)	a = 230°, h = 10°.5; $\alpha = 109°$, $\delta = +36°.5$

Parabolic heliocentric velocity was assumed in computing the zenith correction, as usual. If a part of the train remained visible for 30 seconds from S2 which was well over 200 miles distant from the nearest portion, it seems quite certain that, for any observers, who had this part of the train near their zenith, it would have lasted far longer. A good report from western Maryland or northern Virginia would have settled this important point. The height derived for the part which endured longest, namely 92 km, fits in well with what is known about the limits of the atmospheric stratum in which such trains occur. There is no mention of drift by the observers; had it been large it would probably have been noted. This meteor is not in F. O. Reprint No. 60 as the greatest reported duration of the train was only half a minute, which was below the usual lower limit for durations in that publication.

The other fireballs reported to us for the interval 1936 October 20 to 28 are as follows: 1936 October 20/21, 11:00 p.m., C.S.T., G. H. Fentriss, Nashville, Tennessee, from $2^h\ 59^m$, $\delta = +21°$ to $\alpha = 0^h\ 45^m$, $\delta = -6°$; duration 4 seconds, train 3 seconds, magnitude 0; white. Evidently a sporadic meteor. October 21/22,

12:05 A.M., E.S.T., Dr. J. C. Bartlett, Jr., Baltimore, Maryland, brilliant, yellow-orange, swift, passing between α Ori and the Sword and at a tangent to the latter. Train visible 2 seconds and very brilliant, showing undulations throughout its length before disappearing. This was an Orionid. October 21/22, 0824 G.M.T., Second Officer J. H. Cleary, *Am. S. S. Paulsboro* . . . $\lambda = 87° 07'$ W, $\phi = 26° 05'$ N . . . "a bright bluish meteor . . . appeared near Sirius, traveled in a southerly direction, and disappeared near Canopus, leaving a trail which remained visible for about 11 minutes. An unusually loud report was heard during the passage of the meteor. Weather clear." This is No. 1214 in F.O. Reprint No. 60. It almost certainly was an Orionid. October 21/22, 4:35 A.M., C.S.T., F. W. Bushong, Port Arthur, Texas, magnitude 0, yellow, by Canopus, an Orionid. October 22/23, $5:52 \pm 2$ P.M., E.S.T. For this fireball we have 3 observations, but the coordinates given or derived from the drawings of the path do not permit a solution, though certainly referring to the same fireball. The observers were A. N. Spitz, S1, and I. D. London, S2, of Philadelphia, and Mrs. R. C. Bowie, S3, of Baltimore. In order they report: S1, magnitude —1, white, 1½ seconds, trail $4° \pm 1°$ and disappearing immediately. S2, ¼ apparent size of Moon, $1 \pm$ second, silver-white, curved path. S3, 10 times brilliancy of Venus, pure white, no train, curved path. All saw it in the south or southwest part of the sky and in southern declinations. It was not an Orionid. Even in the twilight it must have been a really exceptionally bright object. October 22/23, 11:32 P.M., E.S.T., Angie Marecki, Baltimore, Maryland, very bright, 15° path, no other data. October 22/23, 4:00 G.M.T., J. C. Artonius, *Dutch S.S. Alkmaar*, $\lambda = 60° 37'$ W, $\phi = 23° 51'$ N, . . . "clear weather. A meteor appeared in the neighborhood of Aldebaran traveling to Saturn, increasing in brilliancy and size, bluish white in color. Altitude approximately 65°, trail 60°, in the beginning, of which remained a part of 5° white, a grayish color for about half an hour, enlarging in length and drifting away in a west northwest direction, getting into an arc form." This is No. 1216 in F.O. Reprint No. 60. The fireball was an Orionid. October 23/24, 081441 G.M.T., Second Officer G. W. Sites, *American S.S. Commercial Alabaman*, $\lambda = 78° 54'$ W, $\phi = 27° 45'$ N, . . . "brilliant greenish meteor, about twice the size of Venus, was observed in the vicinity of Alpheratz, bearing 293°, . . . altitude 23°. The body dropped vertically . . . disappeared . . . altitude of about 13° . . . visible . . . about 3 seconds. Sky clear." This fireball was certainly an Orionid. October 27/28, 9:05 P.M., E.S.T., R. V. Shutts, Brookline, Pennsylvania, from about 2° above Fomalhaut almost perpendicular to horizon, 4 seconds duration, brighter than Venus, pale green, few reddish sparks left behind but no train. This was not an Orionid.

The reports copied here—incidentally those from ships are taken from Hydrographic Bulletins, U.S.N., or Marine Division, U. S. Weather Bureau, reports—indicate that the nine days in question furnished a number of noteworthy fireballs. Most, by no means all, belonged to the Orionid stream. In Meteor Notes for December, 1936, January and February, 1937, will be found considerable data and discussion of the 1936 Orionids. Many other brilliant meteors, seen during regular periods of observation at this epoch, are not mentioned here. All fireballs in these Notes were seen casually.

Flower Observatory of the University of Pennsylvania, Upper Darby, Pennsylvania, 1944 January 3.

Contributions of the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD
Department of Astronomy, University of California, Los Angeles 42

Concerning the Meteor Observed on January 30, 1868, which Fell thru the Atmosphere as a Shower of Stones at Pultusk in the Kingdom of Poland

J. G. GALLE [1812-1910]

Translated by WALTER H. HAAS

[*Continued from the January Issue*]

THE PROBABLE CAUSES OF THE DISCREPANCIES BETWEEN THE OBSERVATIONS MADE AT NEAR AND REMOTE STATIONS

If, at Sokolow, the time from the luminous appearance to the detonation amounted to only 20 seconds in reality, then the distance of the bursting point would have been only 0.9 mile, and, if this point was seen at a height of 50°, it would have been at a horizontal distance of 0.6 mile and only 0.7 mile above the Earth's surface. This distance and the azimuth of 15° W. of N. would be consistent with the statement from Sielc, where the bursting was seen almost in the zenith and the detonation followed 10 seconds later. However, such a low altitude of the bursting point is completely incompatible with the observations at Danzig, Breslau, Kock, and other places, as was previously mentioned also for Warsaw. One is therefore compelled to suppose either very erroneous estimates of the time-interval or, as is more probable, differences between the luminous phenomenon of bursting and the final extinguishing of the falling stones, for some point of the fall must be hypothesized at which the light ceased, since meteori[ti]c stones have frequently and usually reached the Earth's surface in a heated condition, whereas examples of a luminous glow probably constitute exceptions only. Immediately after the dispersal at the bursting point, the stones were still fully luminous. However, during the 1½-minute fall (which was very slow at first, in the very cold regions of the atmosphere), not only was the velocity necessary to the development of light and heat no longer present, but, instead, the contact with very cold air served to expedite cooling during this slow motion; nevertheless, the larger pieces, especially, still remained luminous down to a considerable depth, for one saw them drop in long arcs at Warsaw. However, the luminosity decreased considerably; for the remote stations, the meteor ended at the bursting point; at closer ones, on the other hand, one could follow the burning pieces to an even lesser height; and, at the places of the fall, to a height of less than a mile. It may be regarded, accordingly, as evident that, at the places of the fall, widely deviating and doubtful intervals of time from the luminous phenomenon to the detonation should result; such should be true also of statements of the height of extinction for the different individual places and observers. In order to clarify the much shorter time from extinction to detonation, one has to consider that the sound required $2^m\,5^s$ to arrive from the bursting point, at a height of 5.6 miles; but the stones dropped in $1^m\,32^s$, if the air resistance, which increased this latter time somewhat, be neglected. Hence, if the observers in the vicinity of the fall followed the luminosity down to a lesser

height, there thus elapsed for them hardly half a minute from extinction to detonation, and this value agrees well enough with the preceding statements of 20 seconds and 10 seconds. Finally, it does not appear impossible also that the report from Makoff, apparently so contradictory, about a dark cloud's moving from east to west, is not an error. If Sielc, in the district of Makoff, where the largest stone dropped, lay farthest northeast, then the great proportion of the falling stones must have appeared to the southwest at this place and could have been seen, after having been actually extinguished, as a dark cloud in the direction of the Moon. However, their descent occurred in the line from the zenith to the southwest; there was, accordingly, an apparent motion in the sky from northeast to southwest, and this motion was in fact exactly opposite to the preceding true motion of the meteor[ite] in the atmosphere. Moreover, one would have to conceive of such a cloud as consisting less of the characteristic stones but, instead, more probably, of a numberless host of exceedingly small particles, likewise present, which became extinguished at a great height and fell more slowly in consequence of the greater air resistance, or even remained suspended for a long time.

The Whizzing which Preceded the Detonation: New Evidence thus Furnished of the Great Height of the Point of Detonation

As stated previously, the interval of time which the sound required to arrive at the Earth's surface from the point of explosion, 5.6 miles high, amounted to $2^m\,5^s$, altho the time of descent of the stones from this point was only $1^m\,32^s$. In computing the latter figure, no consideration was taken of the air resistance, which cannot be accurately calculated; likewise, the initial sideways and upward, and hence somewhat parabolic, motions of the exploding stones were ignored. Both causes acted together to increase the time of fall somewhat. However, in the very rarefied air over the greatest part of the path, the change in the time of fall could not have been important, and the arrival of stones on the Earth's surface could have ensued 20 to 30 seconds before the arrival of the sound phenomenon connected with the bursting. This conclusion agrees in the most satisfactory manner with the fact reported from all villages in the region of the fall, that a whizzing, like escaping steam, *preceded* the detonation; it was caused doubtless by stones falling in the immediate vicinity, with the maximum velocity of cannon balls. Such falls must have continued over a certain interval of time, since the stones, even if they left the bursting point almost simultaneously, still could not have reached the Earth at the same time because of their different paths and the varying resistance of the air. Hence, the observed whizzing and crackling could probably have continued at individual places up to the time of the detonation. If the bursting and the detonation had occurred at a lesser height, *e.g.* (as one might infer on the basis of the observations at Sokolow and Sielc), at a height of only 0.7 mile, then sound would have required 16^s to arrive, but the stones themselves would have required 33^s, so that the crackling (generally much weaker in this case) could have commenced only 17^s after the detonation, a thing which would directly contradict the consistent observations; one has therein a new, definite proof that the detonation could not have occurred at so small a height.

The so-called Explosion or Bursting of the Meteor[ite] and the Sound Phenomenon Connected with it

The customary manner of expression, according to which the phenomenon

of a dispersal of the meteor into luminous sparks (which is associated usually with the vanishing of the meteor) is called by the name of "explosion" or "bursting," is based on reasons which will be discussed later. This mode of speech is not to be taken literally, as corresponding to a real content of gunpowder; instead, at the point in question, there is merely a dispersal of meteor[itic] particles arriving there already separate. However, an assumption of some sort of explosion-like process can apparently not be dispensed with in the explanation of [meteoritic] sound phenomena; other explanatory reasons are not readily found for the characteristic sequence of sounds beginning with one or several main detonations. It is not proposed to discuss here whether all meteor[itic] stones and smaller meteor[itic] particles undergo any essential change in size while in transit thru the atmosphere; *i.e.*, whether, during the melting process in the atmosphere, small particles combine with larger masses or whether many larger pieces actually burst into smaller fragments during the rapid heating of their outer surfaces. In any case, a host of distinct, individual bodies may be assumed in general to be in existence during the *entire* passage thru the atmosphere. Before entering the atmosphere these bodies may be thought of as arranged according to arbitrary laws and held together by arbitrary forces; *e.g.*, the largest pieces may be in the middle, or at the front end, or at the rear end [of the swarm]. After the bodies enter the atmosphere, however, these arrangements must immediately take on a different aspect according to another principle, since the resistance of the air and friction are added to the forces previously effective. The action of air resistance will be seen to be very important, since one has to conceive of the meteor[itic] clouds as consisting of individual particles smaller, and of much smaller mass, than [those in] comets and therefore held together by forces just as weak.

The momentum with which a body penetrating the atmosphere overcomes the resistance of the air depends, for equal masses, upon the size and the shape of the outer surface. Differences of any sort in the densities of the bodies will therefore change the resistance of the air, which will be smaller for the denser body. For equal densities and the same shape of the outer surface, the larger pieces will overcome the resistance more easily, because the outer surfaces do not increase in proportion to the mass and the volume; thus, one and the same mass, divided into smaller pieces, which are of the same shape, will experience more resistance in the divided condition, since the outer surface which it offers to the resisting air is then larger. Therefore, if one assumes the density and the shape of individual pieces of the meteor[ite] as equal on the average, the momentum that they possess and, therefore, the amount of air resistance that they can overcome will depend entirely upon their *size*. At the moment of entry into the atmosphere, the smaller pieces are immediately checked more strongly than the larger, and the latter will pass the former; consequently, there will occur in general an arrangement according to *size*, the larger in front and the smaller and smallest behind.

Precisely this factor of size will be decisive as regards also [the position on the individual trajectories of] the point of complete nullification of the planetary velocity (such a nullification occurred in and has been demonstrated previously for the present fall); hence, from this point of nullification on, the meteor[itic] stones will fall simply according to the law of gravitation. This thing is explicable if one takes into consideration that for very large velocities (as experiments on artillery projectiles show) the resistance of the air increases very much more

rapidly than in direct proportion to the square of the velocity and that, for a planetary velocity, the density of the air compressed in front of the moving stone appears to exceed every measure of compression known otherwise. Now evidently those stones which are the largest and accordingly overcome the air resistance the most easily penetrate farthest and deepest into the atmosphere, if conditions are otherwise the same. However, the air resistance eventually becomes so great at a height of about 5 miles that in this neighborhood the last vestige of planetary velocity is lost by even the largest stones; furthermore, the stones rebound from the air masses they have compressed as tho from hard elastic surfaces, while these masses suddenly expand again and produce the [characteristic meteoritic] detonations. The space, within which these detonations originate and the dispersal of the stones occurs, will, however, have a circumference of several thousand feet, corresponding to the real size of the meteor[itic] cloud; furthermore, the largest stone will preserve its planetary velocity very much deeper (*e.g.*, a mile farther) than the smaller stones. As a result, [meteoritic] detonations originate and dispersal of [meteoritic] stones occurs in a volume, *V*, of considerable size. It is to this fact that we must look for an explanation of the peculiar sequence of sound phenomena [accompanying the fall of a meteorite].

Altho all the stones follow one another within a very short period of time, perhaps within one second, yet, according to their position in the volume, *V*, at the instant of stoppage, the sounds which they produce in the atmosphere occur at very different heights; indeed, the pieces and the sparks often drop deeper and deeper still at dispersal, as the so-called repeated explosions indicate. The sound of the most deeply descending pieces will accordingly reach the Earth's surface earliest. Since the largest piece in general precedes the others, the chief detonation it produces, also, will thus in general precede the remaining detonations, and, to be sure, the more so, the more the piece in question exceeds the remaining pieces in size. A difference in height of one mile produces a difference in time of 22 seconds. The reports of the smaller pieces which are stopped at greater heights are heard later. If there are present whole swarms of meteor[ite]s which are stopped at heights differing but little, then there will originate a rattling like platoon-fire. Moreover, all this will occur somewhat differently at different stations, according to the changed distance which the sound has to travel; *e.g.*, at Warsaw, the impact of many small stones was much closer [more remote (?)] than that of the largest stone; hence, the chief detonation preceded a weaker crackling.

In concluding our discussion of the sound phenomena, we have still to decide whether they were produced by the vacuum behind the meteor[ite] or by the violent compression and subsequent expansion of the air in front of it. The latter is surely the more probable, since in only that manner are the checking of the velocity and the advance of the sound from a definite point, the point of detonation, to be explained. The far-extended vacuum would produce a continuous sound (whizzing); furthermore, the filling-up of a small vacuum simply by the pressure of the surrounding atmosphere (excessively rarefied in the upper regions, as we know) might not be capable of producing a detonation as strong as [that which] might the sudden expansion of extremely compressed masses of air, assumed to be developed in front of the stone, and by which it is finally stopped and thrown back.

Finally, in order to illustrate particularly the compression of the air in front of the stone, let one take into consideration [the fact] that the resistance which

a circular disk moving against the air experiences depends upon both its size and its velocity. The size of the surface and the velocity are therefore capable of compensating for each other. For a very large disk, at even a moderate velocity, the air in front of it will not be able to escape rapidly enough and will be compressed, as with the wing-beats of birds, and hence stoppage and rebound will ensue. For meteor[itic] stones, the surface is small; in contrast, however, the resistance and the compression of the air are produced by a velocity far exceeding all ordinary measures, and this velocity allows also too little time for a sideways escape of the [relatively] rarefied air. Moreover, if one concedes this very high degree of compression, one will be obliged no less to concede the violent development of heat, which originates by the rapid compression of the air, and will have to seek in such a development one of the most evident causes of the melting and the luminosity of meteor[itic] stones. The assumption of combustion in the ordinary sense in the rarefied upper layers of the atmosphere does not, therefore, appear to be absolutely necessary.

[*To be continued*]

President of the Society: LINCOLN LA PAZ, Department of Mathematics, Ohio State University, Columbus 10

Secretary of the Society: C. H. CLEMINSHAW, Griffith Observatory, P. O. Box 9866, Los Feliz Station, Los Angeles 27, California

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

The Binary Character of SS Cygni-Type Stars: Dr. A. H. Joy of the Mount Wilson Observatory has recently announced the hitherto unrecognized binary character of some SS Cygni variables. He was working on the spectral changes of the variable AE Aquarii, first reported by A. A. Wachmann to be a variable with an Md spectrum and therefore assumed by him to be another long-period variable of the Mira class. Later E. Zinner, from a photographic study of the star, concluded that the variable was like U Geminorum, with a period of 371 days.

Early in 1943 A. N. Vyssotsky announced that he had observed bright lines of calcium, in addition to those of hydrogen, in the star, and this led Joy to conclude that the star belonged either to the SS Cygni class, or to the T Tauri class, both of which types have bright H and K lines.

A series of Mount Wilson spectrograms shows the characteristic features of the SS Cygni stars at minimum light. The observed changes in the spectrum indicate that the source of these lines is one component of a rapidly moving binary system, with a period not over two days. The observed velocity range exceeds 250 km/sec. No lines of the secondary component have been detected to date. SS Cygni and RU Pegasi show similar radial velocity changes.

This is the first time that the binary character of SS Cygni-type stars has been recognized, and Dr. Joy is to be congratulated on this result, one which may have a far-reaching effect on the problem of the cause of variation in this always interesting class of variable stars.

A Year's Observations of Nova Puppis, 1942: More than 750 visual observations of the variation in light of Nova Puppis have come to hand since its discovery by B. H. Dawson in November, 1942. Of these, about 500 were made by members of the A.A.V.S.O., during the first few months after discovery by northern as well as southern observers, and in recent months by the southern observers alone.

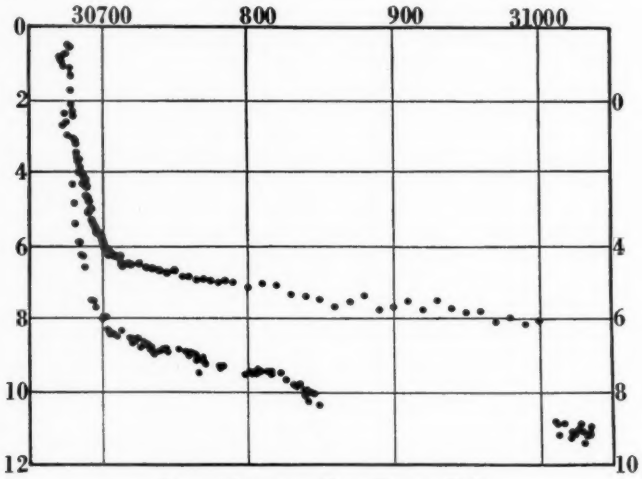
A tabulation of the mean magnitudes is given herewith, at first for frequent intervals of time, approximately each half day, later for one, five, and ten day intervals. In the respective columns are give the mean Julian date, mean magnitude, and number of estimates used in the mean.

TABLE OF MEAN MAGNITUDES

Jul. Day 243	Mean Mag.	No. Ests.	Jul. Day 243	Mag.	Ests.	Jul. Day 243	Mag.	Ests.
0672.8	0.80	3	0699.5	5.78	5	0890	7.76	6
0673.6	0.95	2	0700	5.89	10	0900	7.68	4
0674.4	1.04	5	0701	5.96	8	0910	7.50	2
0674.8	0.73	7	0702	6.07	3	0920	7.75	4
0675.6	0.75	4	0703	6.10	8	0930	7.43	3
0675.9	0.50	6	0704	6.11	7	0940	7.70	1
0676.8	0.54	10	0705	6.28	6	0950	7.80	1
0677.5	1.15	8	0706	6.25	4	0960	7.80	1
0677.9	1.34	18	0707	6.29	9	0970	8.07	3
0678.4	1.31	8	0708	6.30	4	0980	7.93	3
0678.9	1.73	17	0709	6.26	11	0990	8.18	6
0679.5	2.16	9	0710	6.22	9	1000	8.02	5
0679.9	2.33	10	0711	6.30	5			
0680.5	2.45	8	0712	6.38	8			
0680.9	3.03	15	0713	6.29	11			
0681.5	3.08	6	0714	6.50	4			
0681.9	3.23	10	0715	6.42	5			
0682.6	3.45	8	0716	6.44	5			
0682.9	3.66	12	0717	6.48	4			
0683.5	3.74	5	0718	6.50	6			
0683.9	3.70	4	0719	6.48	5			
0684.5	4.04	5	0720	6.49	25			
0684.8	3.90	7	0725	6.50	33			
0685.5	4.04	7	0730	6.58	30			
0685.9	4.11	9	0735	6.60	20			
0686.5	4.37	6	0740	6.63	10			
0686.9	4.20	9	0745	6.73	12			
0687.5	4.45	4	0750	6.68	8			
0687.9	4.70	5	0755	6.82	5			
0688.5	4.48	4	0760	6.80	5			
0689.0	4.80	2	0765	6.90	2			
0689.5	4.72	4	0770	6.92	6			
0689.9	5.10	4	0775	6.96	5			
0690.4	4.85	2	0780	7.00	4			
0691.0	5.08	4	0785	6.94	5			
0691.5	5.02	4	0790	6.98	5			
0691.9	5.00	4	0800	7.15	9			
0692.5	5.37	3	0810	7.00	10			
0692.9	5.32	4	0820	7.07	23			
0693.9	5.42	5	0830	7.33	17			
0694.7	5.53	13	0840	7.38	18			
0695.7	5.75	6	0850	7.46	13			
0696.7	5.64	9	0860	7.66	16			
0697.8	5.68	5	0870	7.52	6			
0698.8	5.67	7	0880	7.37	6			

For comparison purposes the mean light curve, plotted from the tabulated values, and the light curve derived by Edison Pettit from his photometric observations as made at Mount Wilson, are shown in the figure, the Pettit curve displaced two magnitudes below the visual curve. The visual curve is fortunately more nearly complete than the photographic curve, because of the star's more favorable position the sky for southern observers in their winter seasons. Visual observations made since October 1, 1943, have not arrived.

The two curves agree remarkably well until sixth magnitude is attained, when from then on there appears to be a steadily increasing separation between them. This difference may be partly accounted for by color difficulties, or magnitude scales.



LIGHT CURVES OF NOVA PUPPIS, 1942
(Upper: Mean visual; Lower: Photometric by Pettit.)

As will be noted, the decline in light of the nova was rapid during the first month after appearance from maximum magnitude of nearly zero to the sixth magnitude in twenty-five days. During the next twenty-five days the light decreased only six tenths of a magnitude, and from then on, the decline was still slower. The most rapid rate of decrease in light appears to have occurred between November 2 and 18, 1943, when the nova changed at the rate of about 0.4 of a magnitude per day, uniformly over that interval of time.

A Cepheid Variable of Long Period: In the course of the work of the Milton Bureau, Dr. C. Payne Gaposchkin has discussed the 500 observations of HV 3066, 24.1908 Coronae Austrinae, as made by Miss Mary Hunt.

Originally discovered to be variable by Miss Cannon in 1908, Miss Swope later deduced a period of 80 days for the star.

For the observations made between the years 1910 and 1938, it is found that a period of $79^d.57$ prevails, while during the twenty years prior to 1910, a period of $78^d.57$ better satisfies those observations, indicating a definite change in length of period.

The star has a variable spectrum, ranging from A to F at maximum, to K at

minimum as determined by Mrs. Mayall. Although the mean light curve shows a maximum broader than minimum, the early type spectrum and small range of variation—only one magnitude—precludes listing the star as a long-period variable, but instead it should be classed as a Cepheid of long period, of which there are relatively few. The star, although it lies within the range of the RV Tauri class as regards length of period, has none of the characteristics of that group. There is no indication of a secondary minimum, nor is there any evidence of lack of regularity in shape of light curve between cycles, although there is a change in length of period.

Observations: Summary of observations as contributed during the month of December, 1943, by 37 observers, is given below.

Observer	No. Var.	No. Ests.	Observer	No. Var.	No. Ests.
Boone	7	7	McLain	10	18
Blunck	10	14	Meek	38	189
Bouton	44	62	Nadeau	93	100
Buckstaff	11	17	Oheim	7	12
Cousins	49	100	Oravec	5	14
Fernald	233	350	Parks	30	41
Ford	9	9	Peltier	168	235
Garneau	21	21	Robinson	34	68
Griswold	7	16	Rosebrugh	16	71
Halbach	20	24	Schoenke	28	39
Harris	47	47	Segers	14	27
Hartmann	129	136	Sill	93	93
Holt	96	117	Topham	45	45
Howarth	18	18	Vohman	21	24
Irland	15	15	Webb	6	6
Kearons	82	115	Weber	63	63
Kelly	13	15	Young	10	32
de Kock	71	266	—		—
Koons	45	83	37	Totals	2560
Maupomé	51	51			

January 15, 1944.

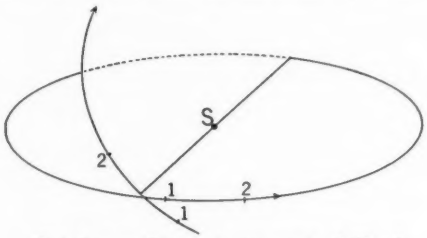
Comet Notes

By VAN BIESBROECK

Comet van Gent-Peltier. This comet has gone through a short-lived period of brightness. We mentioned last month that this object, which in the beginning of December was located too far south for observers on this side of the equator, would probably soon become an evening object. It was, indeed, independently discovered by Leslie C. Peltier of Delphos (Ohio), who has already so many comet discoveries to his credit. He swept it up in his 6-inch telescope in the evening of December 18, and gave the rough position as $23^h\,20^m$, $-16°$, with the indication "moving slowly westward." He called the brightness equivalent to a 7^m star. Not until the next night, when the motion proved to be in a northwest direction, did identity with van Gent's comet become probable. It became a certitude when on December 22 the following elements, computed by Dr. J. Jackson of the Cape Observatory, were telegraphically transmitted:

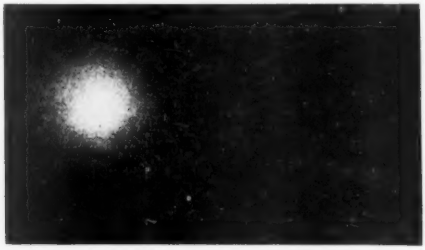
Perihelion Time 1944 January 12.283 U.T.		
Node to perihelion	33° 9′	1943.0
Node	57 50	
Inclination	36 11	
Perihelion distance	0.8738 A.U.	

This computation was evidently based on unpublished observations in the southern hemisphere. The diagram of the orbit shows the space relation of the comet and the earth. After the discovery the comet rapidly increased in bright-



Relative position of the earth (ellipse) and comet (open curve) at the time of discovery (1) and of perihelion (2). S represents the sun.

ness. On December 9 it came within less than a quarter of the sun's distance from the earth. It must have been near naked-eye visibility at that time since on December 18, when Peltier called the magnitude 7, it had already lost in brightness appreciably. The comet is now at perihelion but it is seen that it recedes rapidly from the earth while remaining for several months north of the ecliptic. The comet has apparently not shown any great activity physically. When first seen here on December 19 it showed a sharp nucleus centered in a spherical coma



COMET VAN GENT-PELTIER

(Drawing from a photograph taken December 24 with the 24-inch reflector of the Yerkes Observatory.

of about 5′ in diameter which grew even to 6′ on the following nights. A few days later, December 24, a longer exposure showed a slender tail reaching beyond the edge of the plate, one degree from the nucleus. Finding it difficult to reproduce photographically I made the drawing herewith showing the appearance of the comet with the tail pointing away from the direction of the sun. When last seen here, January 5, the comet had dropped in brightness to a magnitude

estimated as 9, but this may be affected by the nearness of the moon. From now on the distances from both the sun and the earth are increasing, so a rapid decline is to be expected. With large telescopes observations may, however, be possible for some time in the evening sky. After the middle of February, when conjunction with the sun occurs the comet becomes a morning object but it will be quite faint by then.

PERIODIC COMET COMAS SOLÁ has not shown much change during the last month. The magnitude hovers around 12 and from the well-condensed nucleus emanates a short tail in a direction opposite to that of the sun. It is well located in Aries and later in Taurus and might perhaps be in reach of medium sized telescopes.

EPHEMERIS OF PERIODIC COMET COMAS SOLÁ

1944	α h m	δ ° ′
Feb. 8	2 30.0	+16 36
16	43.7	18 32
24	2 58.7	20 27
Mar. 3	3 15.1	22 19
11	32.9	24 5
19	3 52.1	25 45
27	4 12.4	+27 16

PERIODIC COMET D'ARREST has been followed here further but it becomes a difficult object. While the magnitude was about 15 by the end of December it shows less condensation and becomes an extremely diffuse nebulosity.

Both periodic comets DANIEL 1909 IV and SCHAUMASSE are still unaccounted for and will probably be missed at this return. The only other periodic comet expected this year is ENCKE's which is, however, not due until this summer.

Williams Bay, Wisconsin, January 11, 1944.

General Notes

The Annual Meeting of the Royal Astronomical Society of Canada

The annual at home of the Royal Astronomical Society of Canada was held in the Physics Building of the University of Toronto on Friday evening, January 21, 1944, with A. Vibert Douglas, M.B.E., Ph.D., presiding. The General Secretary, Mr. E. J. A. Kennedy, was called upon to present the report of the Committee on the Chant Medal, which is given each year for the most outstanding achievement among the non-professional members of the Society. This year the medal was won by Mr. Cyril G. Wates of Edmonton, Alta., who had constructed a telescope now in use by the University of Alberta. The Presidential address by Dr. Douglas was on the subject "Astronomy in a World at War." Professor D. S. Ainslie gave some demonstrations of the absorption of spectra, and experiments of sound vibrations.

Refreshments were served and a social hour was spent after the program.

Atmosphere of Titan.—Dr. Gerard P. Kuiper reports from the McDonald Observatory that he has obtained red and infrared spectrograms of the satellite Titan of Saturn which show an atmosphere resembling that of Saturn and containing methane and possibly ammonia. This result demonstrates the existence of

a satellite in the solar system having an atmosphere rich in hydrogen. Previous observers had reported an atmosphere on Titan (J. H. Jeans, The Dynamical Theory of Gases, Cambridge, 1925, p. 348, Fourth Edition) but apparently its constitution has not previously been determined.

HARLOW SHAPLEY.

Harvard College Observatory, Announcement Card 677.

Occultation of Jupiter Observed

Following is the report of my observation of the occultation of Jupiter on January 13, 1944. At emersion the sunlight, haze, and low altitude rendered any exact observation very difficult.

IMMERSION

	h	m	s	
Satellite I	7	58	24	E.W.T.
First Contact	8	1	52	E.W.T.
Second Contact		3	12	E.W.T.
Position angle from N thru E		100°		

EMERSION

Second contact	9	5 —	E.W.T. (approximate)
Position angle		250°	(approximate)

COORDINATES OF STATION

Longitude	75°	21.7 W
Latitude	40	2.6 N
Altitude		380 feet

The times were taken with a good stop-watch, checked with an accurate electric clock, and subsequently compared with Naval Observatory time signals. They should be accurate within one second. It was an interesting and beautiful sight.

RICHARD W. BARRINGER.

Radnor, Pennsylvania.

Summary of Sun-Spot Observations at Mount Holyoke College, 1943

Month	No. of Obs.	North of Equator No. of Groups	North of Equator Av. Lat.	South of Equator No. of Groups	South of Equator Av. Lat.	Av. No. Groups at one Obs.	New Groups
January	15	3	+ 4.5	3	— 5.8	1.1	6
February	18	7	8.0	4	3.0	1.6	10
March	18	4	9.2	1	7.5	1.4	4
April	21	3	5.0	3	8.8	1.7	5
May	14	2	6.5	2	21.0	1.3	4
June	27	3	7.3	1	1.0	0.6	4
July	24	3	8.7	1	2.0	0.8	4
August	25	4	10.2	5	8.7	1.7	8
September	19	3	13.0	1	8.5	0.7	4
October	18	2	14.5	2	13.5	0.7	3
November	20	3	12.2	1	9.0	0.8	3
December	17	4	10.9	2	15.0	1.5	4
Totals	236	41		26			59

Average number of groups at one observation..... 1.14
Average latitude of spots north of the equator.....+8.6
Average latitude of spots south of the equator.....—8.9
Number of days without spots..... 51

Judging by the average number of groups at one observation, the number of

new groups, and the number of days without spots (22%), these figures indicate about a 50% reduction in solar activity as compared with 1942. The average latitude of spots has not changed perceptibly. While the latitudes of spots in the two solar hemispheres in 1943 average practically the same, the distribution of spottedness is quite unlike. The value south of the equator is strongly influenced by three high-latitude new-cycle groups first observed on May 17, October 9, and December 15 (at —39°, —25°, and —24°, respectively). Only one other disturbance was found south of —9°. Without these four, the southern average would be —5°.0. In contrast, no group was noted north of +15°, but fourteen groups lay between +10° and +15°. In general the northern hemisphere seems to lag behind or even to reverse direction (*cf.* last months of 1943) in the equatorward trend of the old cycle.

About three quarters of these observations have been made by Miss Helen Pillans. Data from January 5 to February 1 were secured through the kind cooperation of observers at the Ladd Observatory, Brown University.

ALICE H. FARNSWORTH.

John Payson Williston Observatory, South Hadley, Mass., January, 1943.

A Portrait of Nicholas Copernicus

A portrait of the famous sixteenth century Polish astronomer, Nicholas Copernicus, which was painted by Maxim Kopf early last year in connection with the four-hundredth anniversary of the death of the man now characterized as the Father of Modern Astronomy, was formally presented to Dr. Harlow Shapley for the Harvard Astronomical Observatory on February 3 in Cambridge, Mass., by Dr. Stephen P. Mizwa, executive director of the Kosciuszko Foundation under whose auspices nation-wide observances of the Copernican Quadricentennial were held on last May 24 and throughout the year 1943.

Dr. Shapley, who has been director of the Harvard Observatory since 1921, served as chairman of the Copernican Quadricentennial National Committee. Through his leadership, scientists, educators, and leading citizens were brought together in meetings throughout the country to pay tribute to the man whose discoveries of the interrelated movements of the planets, including the earth, and the sun not only changed man's conceptions of the universe but eventually paved the way for the freedom of scientific inquiry for centuries to follow.

In announcing the gift of the portrait to the Harvard Observatory, Dr. Mizwa paid special tribute to Dr. Shapley as one of America's eminent astronomers, who is president of the American Academy of Arts and Sciences, and of the American Astronomical Society, and who "conducted the 400th anniversary celebration with grace and distinction."

"The Kosciuszko Foundation saw fit to present the painting to Harvard as an expression of its gratitude to Dr. Shapley," he added, "and also because of the fact that the Harvard Observatory, although it does not have the largest telescope, is a part of the oldest university in this country just as the University of Krakow, Copernicus' alma mater, was the oldest in Poland. It is interesting to note at this time that through Dr. Shapley's efforts and goodwill after the last war, a telescope from America was made available on loan to the University of Krakow for an indefinite period when that center of learning was again opened up for the same kind of truth and light for which Copernicus is to us today such a dynamic symbol."

The Kosciuszko Foundation in sponsoring the Copernican Quadricentennial carried out one of the several aspects of its program for the promotion of intellectual and cultural relations between Poland and the United States. Since its organization in 1925, it has emphasized the exchange of students, research scholars and professors between the two countries. During the war years, however, considerable aid has been given to Polish refugee scholars and to the collection of a scientific library of medical books and journals in English for use by the Polish Medical Faculty at the University of Edinburgh. This is now the only Polish institution of higher learning in existence. Dr. Henry Noble MacCracken of Vassar College, has been president of the foundation, and Dr. Mizwa, executive director, since its inception.

Bringing Astronomy to the Blind

At the request of the principal, Mr. Cowgill, of the Pennsylvania Institution for the Instruction of the Blind, at Overbrook, I atempted a talk on some of the well-known elementary features of Descriptive Astronomy. In giving such talks in the past, before school and church groups, I have found that the aid of lantern slides can hardly be over-estimated, as well for the lecturer as the audience. With such help precluded, however, one is forced to rely upon "word pictures" alone in endeavoring to hold the attention of those deprived of sight, but who in this case gave every evidence of interest in the subject.

It was remarkable how closely the blind pupils followed the development of astronomical truth, making the lecturer feel humble indeed as they seemed to absorb the facts about the solar system, the speed of light, the distances of the stars, the characteristics of the nebulae, and the existence of universes beyond our own.

This is the Institution that was the alma mater of the eminent blind organist, David Duffield Wood, who in his earlier years became so proficient in mathematics, under the teaching of James G. Blaine, the statesman, that when the latter once spoke of Wood's devotion to music, remarked that "what science had lost music had gained," assuring his friend George W. Childs of the old Philadelphia *Public Ledger* that the organist might have become one of the world's great mathematicians.

In beginning my talk I realized that there is no essential difference in mentality between the blind and the seeing, and made no effort to suppress necessary allusions to what the latter only can fully appreciate regarding the astronomers' means of research—the telescope, the spectroscope, and the camera. Yet I found that lack of sight was no obstacle to a deep interest in these things and it was gratifying to watch those intent faces, full of expression, as they took in the story-entitled "A Roundabout Journey Through the Heavens"—with their minds' eye.

As introduction to explaining the utility of the "light year" in measuring celestial distances—but without mentioning parsecs and megaparsecs—I called attention to the inadequacy of the mile as a unit in gauging the immensity of space, comparing it with the enumeration of geographical distances in inches. I felt that my audience readily grasped the lesser difficulty of comprehending the span of the Atlantic Ocean as three thousand miles, versus two hundred million inches, as well as the extension of the light year to light centuries and light millenniums for the same reason.

Pupils such as these had in past years given wonderful renditions of the great oratorios under the leadership of organist Wood, demonstrating capacity that could as well assimilate astronomical facts and theories. After the talk the head of the science class invited me to answer questions, the foremost of which, as usual, related to the habitability of other worlds; but it was startling to be asked something about the colors of the stars. The answers to some queries often tax the ingenuity of the astronomer, whose explanations must frequently end with an honest "We don't know."

The foregoing experience strengthens my conviction that the study of Astronomy need not be denied the unfortunates lacking eyesight.

H. B. RUMRILL.

Tredyffrin Observatory, Berwyn, Pa.

Total Solar Eclipse of January 25, 1944

The only report of this event that we have seen to date is that transmitted by *Harvard College Observatory Announcement Card, 680,* as follows:

The Director of the National Astrophysical Observatory at Tonanzintla, Senor Luis Enrique Erro, has transmitted telegraphically a report on the Mexican Eclipse Expedition to Peru which was led by Dr. Joaquin Gallo, Director of the National Observatory at Tacubaya, who wrote on January 27th from Chicalyo, Peru as following:

"Sky clear, seeing good. Contrast between corona and sky light comparatively feeble, due perhaps to low altitude of the sun. Sky illumination intense in comparison with other eclipses observed by Gallo. All plates taken came out all right except one with the long focus camera. Developing of plates presented serious difficulties that were happily overcome. Seventy-five per cent of observing program was satisfactorily carried out. On first inspection no traces of polarization are apparent on polaroid plates. This is by no means a final result. Duration of totality was two minutes, forty seconds by actual count by Gallo against his previous computation of two minutes, forty three seconds. Lima astronomers calculated two minutes, forty-seven seconds, and obtained from their observations two minutes and fifty seconds."

HARLOW SHAPLEY.

February 15, 1944.

Book Review

Henry S. Pritchett, A Biography by Abraham Flexner. (Columbia University Press, New York, 1943. $2.75.)

"Opportunity never caught him unawares," says Dr. Flexner in concluding his interesting account of this "ideal citizen" (p. 170), this "thoroughly civilized human being" (p. 172), best known perhaps as the first President of The Carnegie Foundation for the Advancement of Teaching. This office he held for a quarter of a century (1908-1933).

But Henry S. Pritchett had an unusually varied career, which included three years of service as Superintendent of the U.S. Coast and Geodetic Survey

(1897-1900), the presidency of The Massachusetts Institute of Technology (1900-1905), the presidency of the Teachers Insurance and Annuity Association (1918-1930), and the acting-presidency of The Carnegie Corporation (1921-1923).

He is characterized by his biographer as a man "fundamentally concerned with doing things well, regardless of tradition or bias" (p. 68).

Of particular interest, perhaps, to the readers of POPULAR ASTRONOMY is the statement (p. 172): "He never ceased to be an 'astronomer'," explained by the further remark "he reasoned from principles of the soundness of which he had convinced himself by careful reflection." As a matter of fact, Henry S. Pritchett was committed to a scientific career as a young man by the fact that his father, Carr Pritchett, created and directed an astronomical laboratory at Central College in Fayette, Mo. The son started his career as an astronomer in 1880, in the Naval Observatory in Washington. While on the faculty of Washington University in St. Louis (1881-1897) he was astronomer-in-chief of a commission that sailed for New Zealand to observe the transit of Venus (in 1882). He secured his doctorate in astronomy under Seeliger at Munich in 1895.

Yet for a scientist Dr. Pritchett showed an unusual comprehension of the part the humanities and the social studies play in our life. In this connection mention might be made of his presiding at the dedication of the Gennadeion Library at Athens in 1925, and his participation in the modernization of equipment—steel stacks and card catalogs—in the Vatican Library in Rome. Both of these humanistic enterprises were financed by the Carnegie Corporation. At Athens Dr. Pritchett said (of The American Classical School): "This school stands as a perpetual reminder of the spiritual and intellectual debt that the great new world owes to Greece."

High tribute is paid Dr. Pritchett as a man in the statement made by a colleague: "One had the feeling in his presence that the world could not go very far astray."

Dr. Flexner has produced in this book a vivid picture of an unusual man, whose influence upon education was as great as it was significant.

CHARLES C. MIEROW.

Carleton College.